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ORIGINAL ARTICLES.

I.—The Gigantic Ceratopsidæ, or Horned Dinosaurs, of North America.[1]

(PART II., continued from p. 199.)

By Prof. O. C. Marsh, Ph.D., LL.D., F.G.S., etc.

The Scapular Arch and Fore Limbs.—The scapula is massive, especially below. The shaft is long and narrow, with a thin edge in front, and a thick posterior margin above the glenoid fossa. The distal portion has a median external ridge, and a thick end (Woodcut, p. 242, Fig. 1, *sc.*).

The coracoid is rather small, and in old individuals may become united to the scapula. It is sub-rhombic in outline, and is perforated by a large and well-defined foramen. No indications of a sternum have yet been found in this group (Woodcut, Fig. 1, *cr.*).

The humerus (Fig. 2) is large and robust, and similar in form to that of *Stegosaurus*. It is nearly as long as the femur in one individual, proving that the animal walked on all four feet. The radius and ulna (Fig. 3) are comparatively short and stout, and the latter has a very large olecranon process.

There were five well-developed digits in the manus. The metacarpals are short and stout, with rugose extremities. The distal phalanges are broad and hoof-like, showing that the fore-feet were distinctly ungulate (Woodcut, Figs. 11–16, pp. 245–246).

The Pelvis.—The pelvis in this group is very characteristic, and the three bones, ilium, ischium, and pubis, all take a prominent part in forming the acetabulum. The relative size and position of these are shown in the diagram (Woodcut, Fig. 4), which represents the pelvic elements as nearly in the same plane as their form will allow, while retaining essentially their relative position in life.

The ilium is much elongated, and differs widely from that in any of the known groups of the *Dinosauria*. The portion in front of

[1] Read before Section C, of the British Association for the Advancement of Science, at the Leeds Meeting, September 4, 1890. See also American Journal of Science (3), vol. xxxvi. p. 477, December, 1888; vol. xxxvii. p. 334, April, 1889; vol. xxxviii. p. 173, August, 1889, p. 501, December, 1889; and vol. xxxix. p. 81, January, 1890, p. 418, May, 1890.

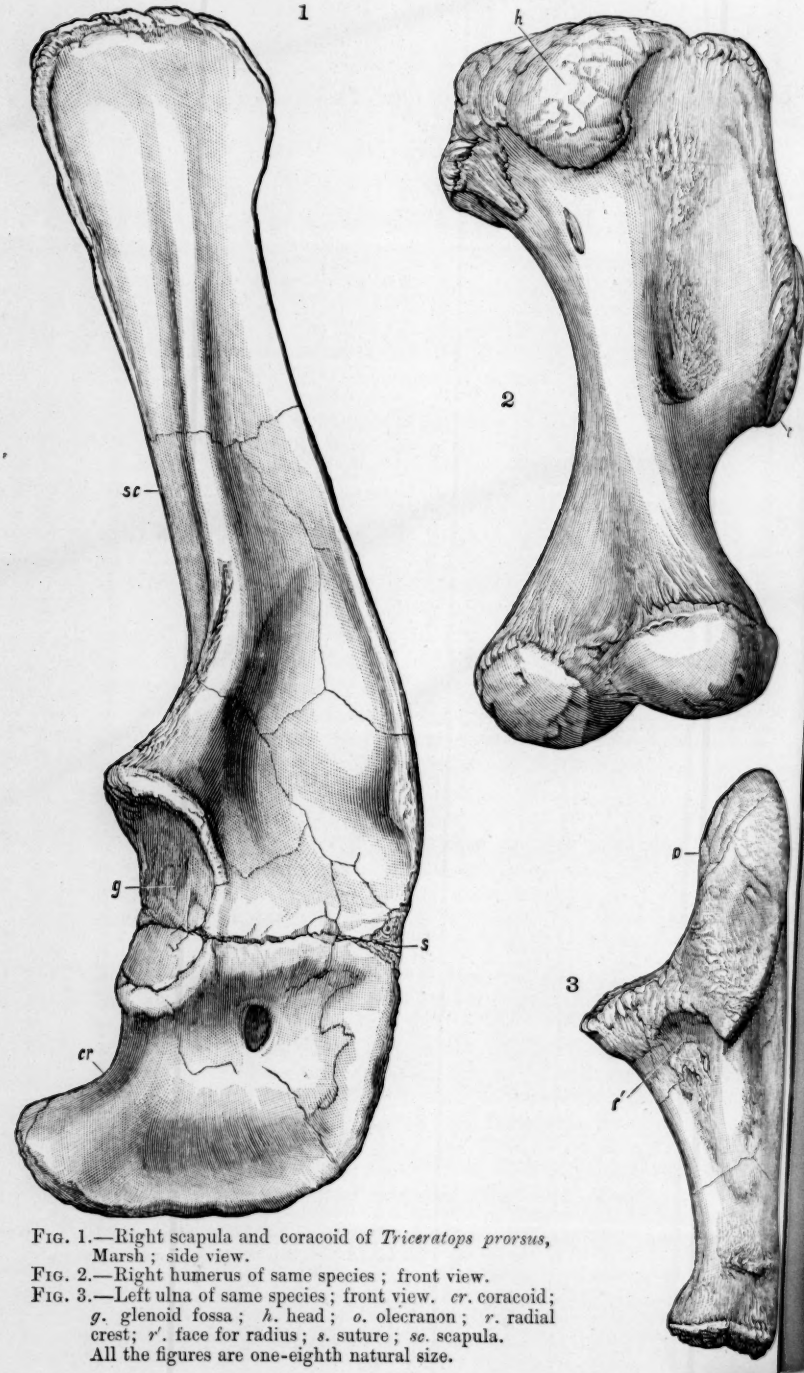
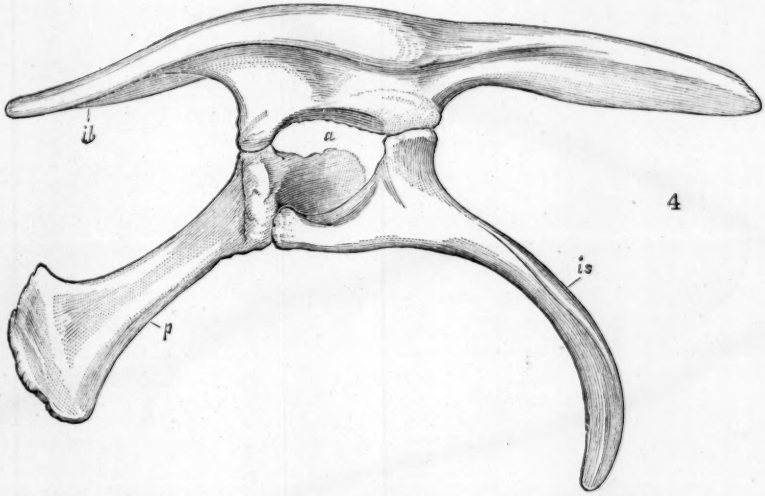


FIG. 1.—Right scapula and coracoid of *Triceratops prorsus*, Marsh ; side view.
FIG. 2.—Right humerus of same species ; front view.
FIG. 3.—Left ulna of same species ; front view. *cr.* coracoid; *g.* glenoid fossa ; *h.* head ; *o.* olecranon ; *r.* radial crest; *r'.* face for radius ; *s.* suture ; *sc.* scapula.
All the figures are one-eighth natural size.



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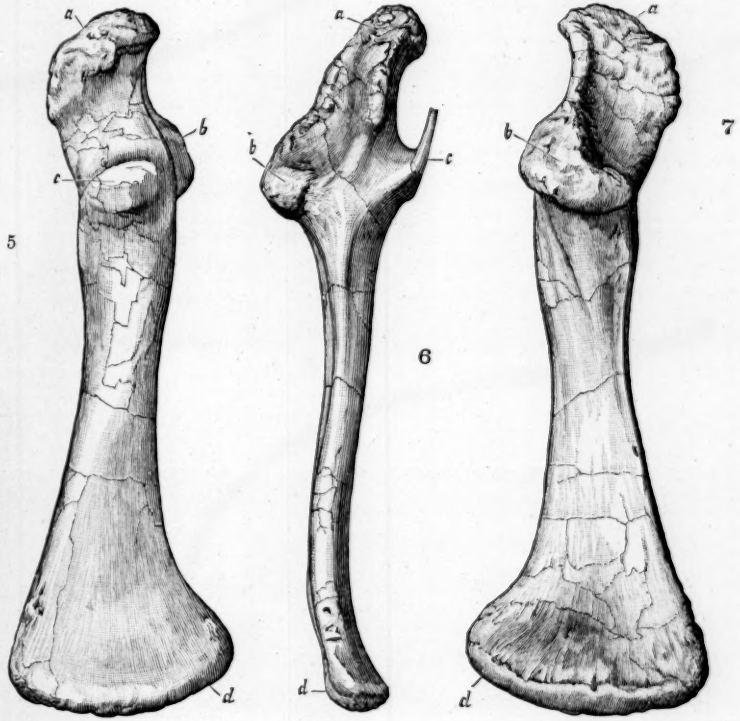

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FIG. 4.—Pelvis of *Triceratops flabellatus*, Marsh, side view, one-twelfth nat. size.
a. acetabulum ; *il*. ilium ; *is*. ischium ; *p*. pubis.
FIG. 5.—Pubis of *Triceratops prorsus*, Marsh, side view, one-eighth nat. size.
FIG. 6.—the same pubis; top view. FIG. 7.—The same, side view.
a. proximal end; *b*. face of ilium; *c*. pubic process; *d*. distal end.

the acetabulum forms a broad, horizontal plate, which is continued backward over the acetabulum, and narrowed in the elongated, posterior extension. Seen from above, the ilium, as a whole, appears as a nearly horizontal, sigmoid, plate. From the outside, as shown in the diagram, the edge of this broad plate is seen.

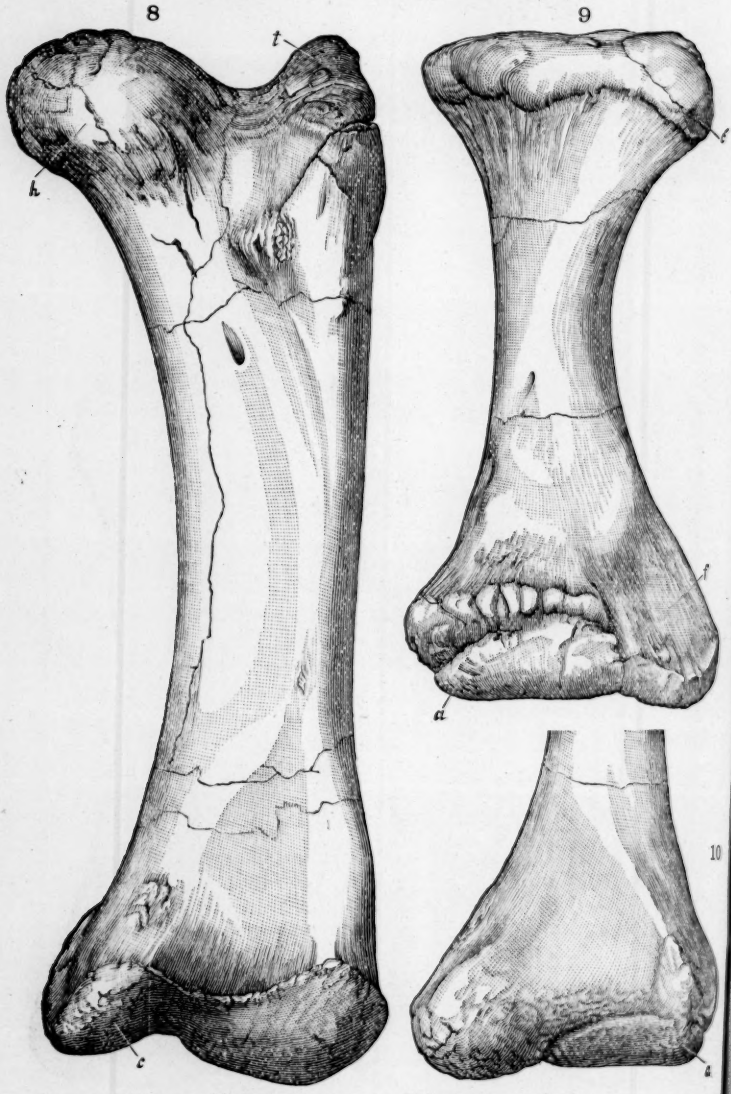


Fig. 8.—Left femur of *Triceratops prorsus*, Marsh (front view).
Fig. 9.—Left tibia of same species (front view).
Fig. 10.—The same tibia; distal end; (back view).
a, astragalus; *c*, inner condyle; *c'* cnemial crest; *f*, face for fibula; *h*, head; *t*, great trochanter. Figs. 8—10 all one-eighth nat. size.

The protuberance for the support of the pubis is comparatively small, and elongated. The face for the ischium is much larger, and but little produced. The acetabular face of the ilium is quite narrow.

The pubis is massive, much compressed transversely, with its distal end widely expanded, as shown in the Figure (5). There is no post-pubis. The pubis itself projects forward, outward, and downward. Its union with the ilium is not a strong one, and is similar to that seen in the pubis of *Stegosaurus*.

The ischium is smaller than the pubis, but more elongate. Its shaft is much curved downward and inward, and in this respect it resembles somewhat the corresponding part of the pubis of the Ostrich. There is no indication that the two ischia met closely at their distal ends, and they were probably united only by cartilage.

A comparison of this pelvis with that of *Stegosaurus* shows some points of resemblance, but a wide difference in each of the elements. The pubis corresponds in its essential features to the pre-pubis of *Stegosaurus*, but the post-pubis is wanting.[1]

The Posterior Limbs.—The femur (Woodcut, Fig. 8) is short, with the great trochanter (*t.*) well developed. The shaft is comparatively slender, and the distal end much expanded. The third trochanter is wanting, or represented only by a rugosity.

The tibia (Woodcut, Fig. 9) is of moderate length, and resembles that of *Stegosaurus*. The shaft is slender, but the ends are much expanded. The fibula is very slender, and the distal end was closely applied to the front of the tibia (Woodcut, Figs. 9 and 10 *f.*). In adult individuals, the astragalus is firmly coössified with the distal end of the tibia, as in *Stegosaurus* (Figs. 9 and 10 *a*, *a*).

The metatarsal bones which were functional are rather long, but massive (Woodcut, Figs. 17–19). Their phalanges are stout, and the distal ones broad and rugose, indicating that the digits were terminated by very strong hoofs (Woodcut, Figs. 20, 21, 22).

All the limb bones and vertebræ in *Triceratops*, and the nearly allied genera, are solid.

Fig. 11.—Metacarpal of *Triceratops prorsus*, Marsh (front view), one-eighth natural size. Figs. 12 and 13.—The same bone; side and back views.

The Dermal Armour.—Beside the armature of the skull, the body also in the *Ceratopsidæ* was protected. The nature and position of the defensive parts in the different forms cannot yet be

[1] The pubis recently discovered, and represented in Woodcuts Figs. 5, 6, 7, has a short, splint-like process, which may, perhaps, be a remnant of a post-pubic element, although it has not the position of the post-pubic bone in other Dinosaurs.

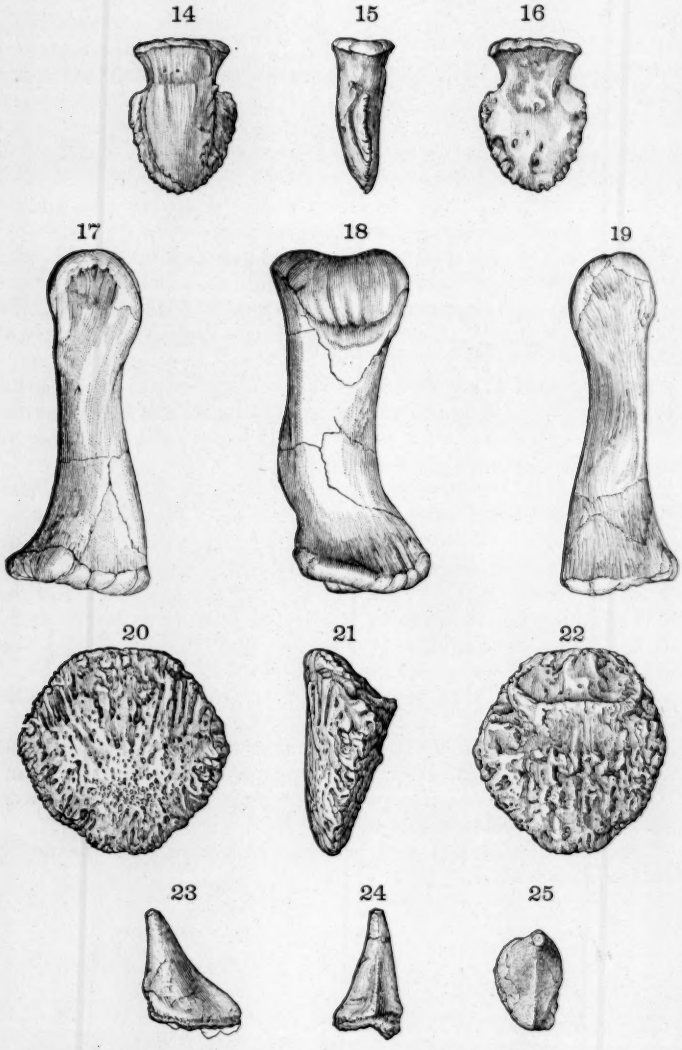


Fig. 14.—Terminal phalanx of manus of *Triceratops flabellatus*, Marsh; front view; one-fourth natural size. Figs. 15 and 16.—Side and back views of same.

Fig. 17.—Metatarsal of *Triceratops prorsus*, Marsh; side-view; one-eighth natural size. Figs. 18 and 19.—Front and side view of same.

Fig. 20.—Ungual phalanx of *Triceratops horridus*, Marsh; front view; one-fourth natural size. Fig. 21.—The same; side view. Fig. 22.—The same; posterior view.

Fig. 23.—Dermal spine of *Triceratops*; side view; one-eighth natural size.

Figs. 24 and 25.—Front and top views of same.

Erratum.—In Geol. Mag. May No. pp. 195, 196, 197, 199, for *Triceratops* '*porosus*,' read *Triceratops prorsus*, Marsh.—Edit. Geol. Mag.

determined with certainty, but various spines, bosses, and plates have been found, that clearly pertain to the dermal covering of *Triceratops*, or nearly allied genera. Several of these ossifications were probably placed on the back, behind the crest of the skull (Woodcut, Figs. 33–34), and some of the smaller ones may have defended the throat, as in *Stegosaurus*.

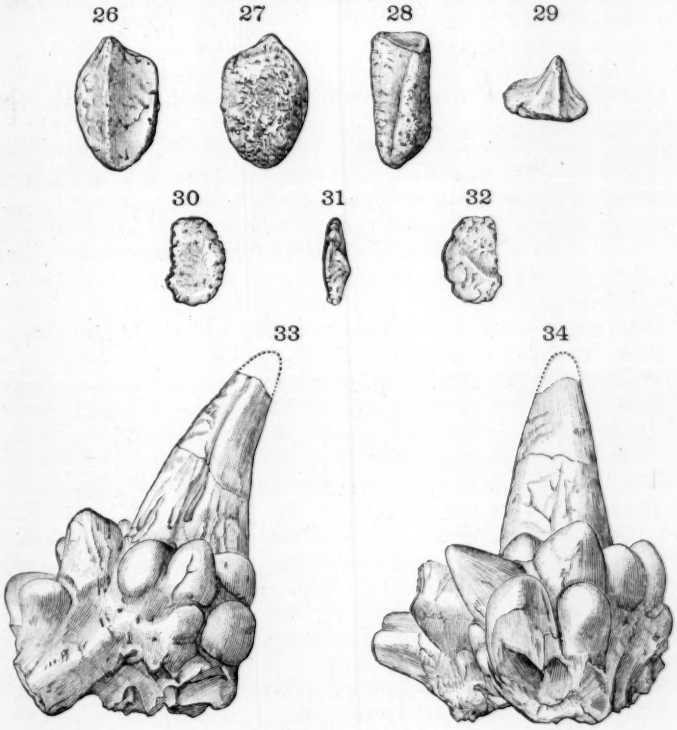


Fig. 26.—Dermal plate of *Triceratops*; top view; one-eighth natural size.
Fig. 27.—Bottom view of same. Figs. 28 and 29.—Side and end views of same.
Figs. 30–32.—Dermal plate of *Triceratops*; top, bottom and side views; one-eighth natural size.
Fig. 33.—Dermal ossification of *Triceratops*; side view; one-half natural size.
Fig. 34.—Front view of same.

The remarkable extinct reptiles here briefly described present many characters which separate them widely from all other known Dinosaurs. Some of these characters are evidently the result of a high degree of specialization, but there are others that cannot be thus explained. The specialization evidently began in the skull, and there reached its greatest development. The peculiar armature of the skull has a partial parallel in the genus *Phrynosoma* among the recent Lizards, and *Meiolania* among the extinct Turtles. A suggestion of the parietal crest may be seen in the existing *Chameleo*,

which offers other points of resemblance in its skull and skeleton. These features, however, indicate only a very remote affinity, and it is among the Dinosaurs alone that this group can be placed, as a distinct family, in the order *Ornithopoda*.

The *Ceratopsidæ* resemble, in various points, the *Stegosauria* of the Jurassic, especially in the vertebræ, limbs, and feet. The greatest difference is seen in the skull, but the pelvic arch, also, shows a wide divergence. In the *Ceratopsidæ*, there is no marked enlargement of the spinal cavity in the sacrum, and there is no post-pubis.

The characters above given are based upon fossils which I have personally investigated, including the type specimens of *Ceratops* and *Triceratops*, on which, mainly, the family *Ceratopsidæ* was established. The material now at my command includes the remains of many individuals, among which are portions of about twenty different skulls, and some of these are nearly perfect. In the memoir now in preparation, I shall fully describe and illustrate all the more important of these specimens, and likewise discuss their relations to allied forms.

The generic names, *Agathaumas*, *Cratæomus*, *Monoclonius*, and one or two others, have been given to fragmentary fossils, which may belong to this group, but these remains, so far as made known, appear quite distinct from those here described.

In conclusion, let me say a word as to how the discoveries here recorded have been accomplished. The main credit for the work justly belongs to my able assistant, Mr. J. B. Hatcher, who has done so much to bring to light the ancient life of the Rocky Mountain region. I can only claim to have shared a few of the dangers and hardships with him, but without his skill and energy, little would have been accomplished. If it is borne in mind that two of the skulls weighed nearly two tons each, when partially freed from their matrix, and ready for shipment, in a deep, desert cañon, fifty miles from a railway, you will appreciate one of the mechanical difficulties overcome. When I add that some of the most interesting discoveries were made in the hunting grounds of the hostile Sioux Indians, who regard such explorations with superstitious dread, you will understand another phase of the problem. I might speak of even greater difficulties and dangers, but the results attained repay all past efforts, and I hope at no distant day to have something more of interest to lay before your readers.

II.—Appendix.—Restoration of Triceratops.

By Prof. O. C. Marsh, Ph.D., LL.D., F.G.S., etc.

(PLATE VII.)

In previous numbers of this Magazine, the writer has given the principal characters of the gigantic *Ceratopsidæ*, or horned Dinosaurs, from the Laramie, with figures of the more important parts of the skull and skeleton.[1] The abundant material now

[1] See Geol. Mag. 1890, January Number, pp. 1–5, and Plate I. Geol. Mag. 1891, April Number, Pl. IV. May Number, Pl. V. pp. 193–199, *ante*, pp. 241–248.

available for examination makes it possible to attempt a restoration of one characteristic form, and the result is given in Plate VII. This figure, about one-fortieth of natural size, is reduced from a large outline plate of a memoir on this group, now in preparation by the writer for the United States Geological Survey.

This restoration is mainly based on two specimens. One of these is the type of *Triceratops prorsus*, Marsh, in which the skull, lower jaw, and cervical vertebræ are in remarkable preservation. The other specimen, although somewhat larger, is referred to the same species. It consists of parts of the skull, of vertebræ, the pelvic arch, and nearly all the important limb bones. The remaining portions are mostly taken from other remains found in the same horizon and localities, and at present are not to be distinguished specifically from the two specimens above mentioned. The skull as here represented corresponds in scale to the skeleton of the larger individual.

In this restoration, the animal is represented as walking, and the enormous head is in a position adapted to that motion. The massive fore limbs, proportionally the largest in any known Dinosaur, correspond to the head, and indicate slow locomotion on all four feet.

The skull is, of course, without its strong horny covering on the beak, horn-cores, and posterior crest, and hence appears much smaller than in life. The neck seems short, but the first six cervical vertebræ are entirely concealed by the crest of the skull, which in its complete armature would extend over one or two vertebræ more. The posterior dorsals with their double-headed ribs continue back to the sacrum itself, there being no true lumbars, although two vertebræ, apparently once lumbars, are now sacrals, as their transverse processes meet the ilia, and their centra are coössified with the true sacrum. The four original sacral vertebræ have their neural spines fused into a single plate, while the posterior sacrals, once caudals, have separate spines directed backward.

No attempt is made, in this restoration, to represent the dermal armour of the body, although in life the latter was more or less protected. Various spines, bosses, and plates, indicating such dermal armature, have been found with remains of this group, but the exact position of these specimens can, at present, be only a matter of conjecture.

This restoration gives a correct idea of the general proportions of the entire skeleton in the genus *Triceratops*. The size, in life, would be about twenty-five feet in length, and ten feet in height. The genus *Ceratops* so far as at present known is represented by individuals of smaller size, and in some instances, at least, of quite different proportions. A third genus, which may be called *Sterrholophus*, can be readily distinguished from the other two by the parietal crest, which had its entire posterior surface covered with the ligaments and muscles supporting the head. In *Ceratops* and *Triceratops*, a wide margin of this surface was free, and protected by a thick, horny covering. The type of the new genus is the specimen described and figured by the writer, as *Triceratops flabellatus*, which

in future may be known as *Sterrholophus flabellatus*, Marsh. There is some evidence that other forms, quite distinct, left their remains in essentially the same horizon of the Laramie, but their true relation to the above genera cannot be settled without further discoveries.

This group so far as at present investigated is very distinct from all other known Dinosaurs, and whether it should be regarded as a family, *Ceratopsidæ*, as first described by the writer, or as a sub-order, *Ceratopsia*, as later defined by him, will depend upon the interpretation and value of the peculiar characters manifested in its typical forms.

The main characters which separate the group from all other known families of the *Dinosauria* are as follows:

(1) A rostral bone, forming a sharp, cutting beak.
(2) The skull surmounted by massive horn-cores.
(3) The expanded parietal crest, with its marginal armature.
(4) A pineal foramen.
(5) The teeth with two distinct roots.
(6) The anterior cervical vertebræ coössified with each other.
(7) The dorsal vertebræ supporting, on the diapophysis, both the head and tubercle of the rib.
(8) The lumbar vertebræ wanting.

The animals of this group were all herbivorous, and their food was probably the soft succulent vegetation that flourished during the Cretaceous period. The remains here figured are from the Ceratops beds of the Laramie, and were found by Mr. J. B. Hatcher, in Wyoming, on the eastern slope of the Rocky Mountains.

III.—Notes on a Collection of Rocks from the Tonga Islands.

By Alfred Harker, M.A., F.G.S.,
Fellow of St. John's College, Cambridge.

THE Tonga or Friendly Islands in the South Pacific Ocean seem to have received hitherto no attention from geologists, and I can find no published information as to their geological constitution beyond the simple record of the existence of volcanoes and coral-reefs. The material of these brief notes was mostly collected by Mr. J. J. Lister, M.A., during the cruise of H.M.S. *Egeria* in 1889; and, through the courtesy of Captain Wharton, R.N., F.R.S., Hydrographer to the Admiralty, I have had the opportunity of examining a few additional specimens collected by Captain C. F. Oldham, R.N., Commander of the *Egeria*, in 1890. In view of the general account of the islands which Mr. Lister is preparing, I notice here only such points as arise directly from an examination of the specimens.

It is well known that most of the Pacific Islands which have been explored seem to be built largely of either volcanic or calcareous formations, usually supposed to be of Recent origin. Indeed the idea seems to have been entertained in some quarters that such was

the universal construction of the islands. Drasche,[1] writing in 1879, restricted this theory to those islands lying eastward of a certain line, drawn from Kamschatka through Japan, the Philippines, New Guinea, New Caledonia, New Zealand, Auckland and Macquarie Islands to the Antarctic Victoria. Even at that time, however, such rocks as clay-slates, greywackes, etc., had been recorded in the Chatham Islands[2] and New Britain,[3] east of Drasche's line, and leptinites,[4] granite, and gneiss[5] in the Marquesas, far to the east, Later researches have proved the existence of numerous crystalline rocks, igneous and metamorphic, in the larger islands of the Fiji[6] and Solomon[7] archipelagos, and suggested that in many other islands such rocks may be only masked by a comparatively thin covering of organic or volcanic accumulations.

It may be inquired, then, whether the Tonga Islands show any indication of the existence of denuded crystalline rocks beneath the newer deposits. No such rocks have been found in place, and the evidence available is very slight. Eua, the most southerly of the larger islands, differs to some extent from the rest in geological structure, and from the eastern shore of this island Mr. Lister collected a boulder, one of many there seen, which is neither a volcanic nor an organic rock. I have described it (Geological Magzine for April, p. 172) as a uralitised gabbro, and, though some petrologists would prefer to name it diabase, it is unlike any superficially erupted lava. Further, there is no doubt that it is derived from the island on which it was found. The only other suggestive point is the rare presence of minute fragments of red garnet and blue tourmaline in the calcareous andesitic sandstones largely developed in the same island. These fragments, blown out from a volcano, point to the existence of metamorphic rocks below, though at what depth it would be idle to speculate.

With the exception of the dykes mentioned below, the volcanic rocks of Eua seem to consist entirely of fragmental accumulations, no lava-flows being seen. Mr. Lister's collection, however, contains a specimen of a boulder from the same locality as the one mentioned above, which is a grey compact-looking andesite of specific gravity 2·618. It shows under the microscope a kind of flow-brecciation which causes us to compare the rock with extruded lavas rather than with the dykes exposed near the locality in question. The rock [1258] consists of very numerous little plagioclase crystals imbedded, with marked parallel arrangement, in an isotropic ground. The felspars are lath-shaped to acicular, and twinned or simple according to their size. There is little or no augite, but an occasional crystal of rhombic pyroxene transformed into pale green

[1] Neu. Jahrb. 1879, p. 265.
[2] See Darwin's "Geological Observations:" cf. Haast, Trans. N.Z. Inst. vol. i. p. 180, 1869, and Hector, *ibid.* vol. ii. p. 183, 1870.
[3] Meinicke, "Inseln des Stillen Oceans," vol. i. p. 133, 1875.
[4] Jardin, Mém. Soc. Imp. Sci. Nat. Cherbourg, vol. iv. p. 55, 1856.
[5] Marcou, "Explic. Carte Géol. de la Terre," p. 185, 1875; authority not cited.
[6] Wichmann, Tsch. Min. Petr. Mitth. vol. v. p. i. 1882.
[7] Guppy, "The Solomon Islands, their Geology," etc., 1887.

fibrous bastite. Magnetite grains and crystals occur sparingly. The most plentiful secondary product is yellow-green pleochroic epidote, which seems in part to replace some of the larger felspars. The slide shows numerous irregularly shaped patches of andesite differing from their matrix. They are sometimes of finer texture, sometimes coarser, or again have a fine ground enclosing porphyritic felspars. These patches do not share in the general flow structure of the rock, and seem to be relics of a solid crust formed on the surface of a *coulée*, and broken up by subsequent movement of the mass.

Mr. Lister notes three dykes exposed on the eastern shore of Eua. These cut through the volcanic deposits, but are older than the overlying limestones, which they do not penetrate. The specimens are of a dull-grey andesite, sometimes showing porphyritic felspars to about an eighth of an inch long, or little dark spots which represent decomposing pyroxene.

Under the microscope these rocks show innumerable microlites of felspar imbedded in an isotropic base. When porphyritic felspars occur, they exhibit Carlsbad and albite twinning and strong zonary banding in polarized light. Augite is not recognizable in the ground-mass, but occurs in more or less idiomorphic crystals, colourless or nearly so in section, among the earlier minerals. With it is associated a pale yellow enstatite in good prisms terminated by the dome (102) [slide 1261]. Magnetite is present either in crystals of the earlier consolidation or in little granules in the ground-mass. As secondary products we find calcite from the felspars, delessite and calcite from the augite, and green dichroic bastite from the rhombic pyroxene [1260]. A specimen [1259] from the northerly dyke shows the usual microlitic ground traversed by distinct branching veins which consist mainly of larger, though still mostly untwinned, crystals of felspar, extinguishing nearly parallel to their length, and perhaps referable to sanidine. These veins are probably segregations marking the last phase in the consolidation of the mass.

The fragmental volcanic rocks of Eua are well bedded in nearly horizontal strata, and exhibit frequent alternations of types differing in degree of coarseness, etc. Some are of the nature of volcanic dust, forming bands of grey to red colour according to their fresher or more decomposed condition. Among the finely divided material of these bands may be recognized little rounded or irregular bits of brown glassy matter, and broken crystals of clear felspar, green augite, and occasionally pale enstatite. The extinction-angles measured on cleavage-flakes of the felspar show that more than one member of the soda-lime series is represented. The same materials are recognized in various red-brown earthy rocks from the higher ground of the island, apparently formed by atmospheric weathering, and in the fine sand from the beds of the rain-channels in the neighbourhood. The fragments in these fine ash-beds are fairly uniform in size, though occasionally a few small lapilli occur. These deposits are mostly free from carbonate of lime, but there

are some which are highly calcareous. Specimens from the northern part of Eua have a white chalky aspect, and effervesce freely with acid, but they contain abundant felspar microlites and broken felspar crystals, some giving nearly straight extinction (oligoclase-andesine?), besides occasional enstatite, etc.

A coarser type of rock, well represented in the collection, may be termed a volcanic sandstone. It resembles an ordinary sandstone of moderately coarse grain, though isolated fragments occur up to about an eighth of an inch in diameter. On the generally yellowish brown surface are seen little scattered broken crystals of black augite and the lustrous cleavage-planes of felspar fragments. Some of the felspar flakes give nearly straight extinction; others are evidently more basic. As before, the bulk of the fragments composing the rock are of brown-stained glassy lava. Good examples come from the mouth of Ana-ahu.

At the last-named locality there is an alternation of harder and softer beds. The softer are of the character just described; the harder differ from them in possessing a cement of calcite, which forms a large part of the rock. These calcareous beds, which occur also in other parts of the volcanic series of Eua, present under the microscope some points of interest. One of these features, the occasional presence of minute chips of characteristic metamorphic minerals, has already been alluded to. Slices [1268, 1273] show that the fragments, some of which appear rolled, are of brown-stained andesite, enclosing many felspar microlites and occasionally a porphyritic crystal. The larger pieces have the spongy character of pumice. Besides the andesitic fragments, are seen little chips of minerals such as might be derived from the same source; clear plagioclase, pseudomorphs of calcite after felspar, and brightly polarising pyroxene; also rarely a grain or two of quartz, seemingly clastic. The matrix of crystalline calcite encloses numerous foraminiferal tests which seem to belong for the most part to Globigerina. More rarely occurs a small chip of shell or a fragment recalling the characteristic structure of an echinoderm plate. The calcareous matrix further exhibits in parts a beautiful oolitic structure, giving the black cross well defined in polarised light. The structure is of the spherulitic type, with radial but not concentric arrangement, and is quite different from the rolled oolitic grains well known in our Carboniferous and Jurassic limestones. It is produced *in situ* by molecular action, as is sufficiently proved by the fact that one of these spherulitic growths occupies each chamber of the foraminiferal tests.

It seems clear that the whole of these volcanic rocks of Eua are of submarine origin. This appears from their uniform and horizontal stratification, the indications of the "sorting" action of water, and the occurrence at various horizons of highly calcareous rocks, some containing marine organisms. Probably some parts of the deposits come from the destruction of volcanic accumulations thrown up above sea-level, such as Falcon Island at the present day, which is being rapidly destroyed by the waves.

The volcanic rocks of Eua are overlain, with evident unconformity, by massive white limestones, and the earlier group must have suffered considerable denudation before the newer was deposited. This appears from the fact that while the horizontally bedded volcanics crop out in the interior at a height of more than a thousand feet, the limestones come down to sea-level on the coast within a distance of half a mile. Further, the dykes which cut through the volcanic deposits terminate without entering the overlying calcareous strata.

The limestones occur in three terraces, and Mr. Lister was led to regard them as elevated reefs. He observed reef-corals on the edge of the lower terrace and on the top of the highest one. An examination of a few thin sections of the rocks showed indeed a comparative want of coral fragments, the rocks sliced, with their abundant foraminifera, some of large size, recalling strongly the Orbitoidal Limestones of Sumatra and Borneo as described by Messrs. H. B. Brady[1] and A. V. Jennings[2] respectively. When good coral remains occur, they are associated with similar foraminifera, etc. [1329]. The specimens have, however, been submitted to Dr. John Murray, whose large experience of calcareous deposits is well known, and, pending the results of his examination, it will be sufficient here to notice the more obvious petrological characters of the rocks.

Some examples, *e.g.* from Maui's Oven, are rough-textured yellowish limestones, in which abundant foraminifera can be seen on a hand-specimen. In general, however, the deposition of secondary calcite has converted the mass into a white or cream-coloured limestone of very compact appearance, not unlike some travertines, but containing sometimes little irregular vacuities which the calcite cement has not filled.

The specimens sliced, whether from the lower, the middle, or the upper terrace, show abundant foraminiferal tests and other organic remains which will not be more closely described in this place. Small oolitic growths are common in the secondary calcite cement, but they are invariably of the spherulitic type. Concentric-coated oolitic grains are conspicuously absent, nor is there any trace of clastic material such as quartz- or shell-sand, volcanic detritus, etc. The only large fossil observed is a cast of a *Cerithium*, not perfect enough for specific determination.

I pass on to the specimens from other islands composed partly or wholly of volcanic accumulations. The purely coral islands, Tongatabu, Vavau, Nomuka, etc., will not be noticed.

Mango (Comango on the Chart) appears to be built entirely of volcanic ejectamenta. Mr. Lister found no lavas except as fragments in the tuffs. These, in the specimens examined, range up to about six inches in length, and have a dull brown decomposed aspect, with in many cases small vesicles filled with calcite. A slice of one [1267] shows a microlitic andesite with marked flow-

[1] Geol. Mag. (2), Vol. II. p. 532, 1875.
[2] Geol. Mag. (3), Vol. V. p. 529, 1888.

structure and much ferruginous decomposition-product. The rock is not porphyritic.

The fragmental accumulations from this island vary much in character. Specimens from the eastern hill are white chalky-looking rocks, in which nothing is to be seen beyond a rare crystal of augite. They are very calcareous, and the residue after treatment with acid is merely a mass of very fine scoriaceous and dusty material with fragments of crystals of felspar, hypersthene (?), apatite, etc. From other parts of the island come fine grey ashes with white spots of decomposing felspar. These are non-calcareous, and consist of minute fragments of brown-stained glass and various volcanic minerals mingled with fine dust. Other rocks unmixed with calcareous matter are, rather, volcanic sandstones, enclosing numerous fragments, usually rounded, of yellow or brown lava, etc. Specimens of coarser texture—volcanic conglomerates—come from the western or Observation Hill. These have a partly calcareous matrix and include fragments of lava usually an inch or more in diameter and of subangular form. In these coarse accumulations occur blocks of coral, specimens of which are as much as six inches across, and have portions of the conglomeratic rock adhering firmly to them.

Nomuka-iki is a small island lying to the south-west of Nomuka. It is described as consisting in its northern part of a flat of coral sand, while the southern and higher portion is of stratified volcanic ashes, alternately fine and coarse, which are well exposed in a cliff on the west, and contain marine fossils. The specimens from here are mostly yellow-brown or greyish ashes of fine texture, only occasionally showing fragments up to an eighth of an inch long, some of which are of decomposing andesite. Little glistening felspars are visible with a lens, besides countless little black dots which seem to be partly altered pyroxene. Some specimens from the upper layers are rather coarser, and show more conspicuous fragments. In these, well-formed prisms of lustrous black augite may be recognized as well as the felspars. The microscope shows that these latter are, as usual, of a triclinic species; that a green, pleochroic rhombic pyroxene occurs, in addition to the green augite; and that yellowish volcanic glass and fine dust are also represented. None of the Nomuka-iki specimens are calcareous enough to effervesce with acid. The only fossil in the collection is a well-preserved *Pyrula*. It rather resembles the Eocene *P. nexilis*, but has more delicate markings, and is perhaps to be matched among later forms.

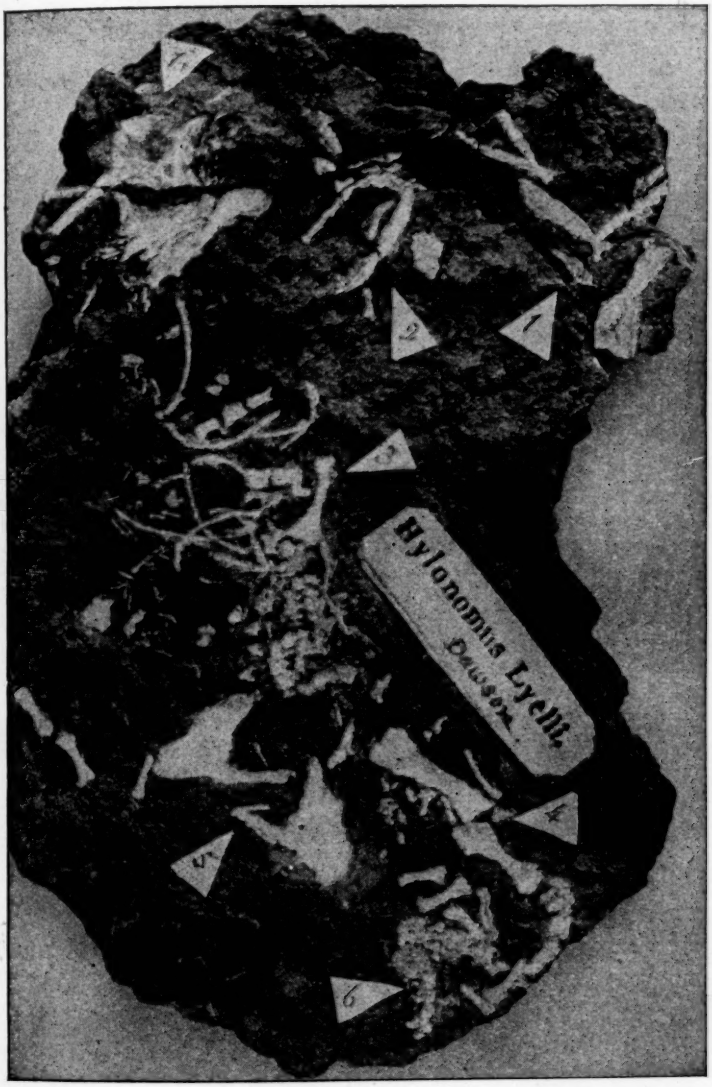
Tonumeia, a small island situated to the south of Nomuka and Mango, consists, according to Captain Oldham's observations, of stratified volcanic tuffs, which are exhibited in a cliff 80 feet high on the west coast, showing a dip of 3° to the south. A specimen (I.) of the finer tuff is a rather fine volcanic ash compacted by a calcareous and ferruginous cement into a dirty yellow-brown rock. In the residue insoluble in dilute acid are recognized chips of a monoclinic and a fibrous rhombic pyroxene with a basic felspar, besides the usual brown-stained glassy and scoriaceous fragments.

Other specimens from this island are pebbles found on the beach. One (II.) is a coarsely amygdaloidal lava, perhaps not a native rock. Two others are black nodules of irregular but rounded form, the larger being two inches in diameter (III.). They have externally a graphitic lustre, while the interior is duller and shows a certain eccentric radial structure. Rough chemical tests indicate some oxide of manganese, and the general characters are those of psilomelane; but the interior is softer, and the specific gravity of one nodule was found to be only 3·54. This perhaps indicates a partial conversion into wad or some other hydrated substance. These nodules are evidently native to the island, and portions of the calcareous matrix in which they have been imbedded are still adherent on their surfaces.

Captain Oldham also collected specimens from the small island Tonua (not named on the Chart) situated north-east of Mango. Of these, an "altered coral sand" (IV.) from the summit of the island seems to be free from foreign admixture; the rest, from a cliff 20 feet high on the north side, are volcanic ashes usually with but little calcareous matter, despite the fact that organic remains are visible in several specimens. These stratified volcanic rocks, with an easterly dip, build the mass of the island. Most of the specimens are soft yellow-white rocks with a lumpy appearance, although the enclosed fragments, up to about an inch in diameter, do not differ essentially from the matrix in which they are imbedded (V. and Va.). Minute glistening crystals of felspar and augite are visible here and there in the dull mass, and the microscope shows only these minerals with an occasional broken needle of apatite, and much fine dusty matter. In other examples from the same cliff the fragments are more distinct, and many of the smaller ones are rolled bits of dark lava (VI. and VII.). These rocks contain numerous organic remains, among which the most conspicuous seem to be the conical tests of Pteropods: a rather indistinct cast of a Gasteropod also occurs—possibly a *Murex* from the form of its canal, although the varices are not very strongly marked. One specimen is traversed by a half-inch seam of fine, non-calcareous character, with a dark grey colour, clearly indicating the stratified nature of the deposits. The microscope shows the usual triclinic felspars and green pyroxene, the felspar crystals and fragments being especially abundant, together with fine volcanic dust and glass fragments. There are also very slender needles of a highly refracting yellow-brown mineral, which has much of the appearance of rutile—a mineral scarcely to be expected in such a connexion.

Falcon Island came into existence owing to a volcanic eruption which occurred in the year 1885.[1] The main mass of the island consists of a fine grey ash, mostly quite incoherent, but containing crumbling lumps. The microscope shows this to be a volcanic dust similar to that so widely dispersed during the eruption of Krakatau. It is composed largely of comminuted crystals, among which are recognized felspars, some with twin-lamellation, green augite, and

[1] A Visit to the newly emerged Falcon Island, Tonga Group, S. Pacific, by J. J. Lister, Proceedings of the Royal Geographical Society, March, 1890.



Remains of Hylonomus Lyelli, Dawson, 1859.

Coal-Measures, South Joggins; Nova Scotia.

(1) Cranial bones and mandibles; (1*a*) Sternal and shoulder bones; (2) Mandible; (3) Humerus, ribs and vertebræ; (4) Hind limb; (5) Pelvis; (6) Caudal vertebræ.

a rather fibrous rhombic pyroxene. Some of the felspars are andesine, but they are not all of one variety. With these minerals occur many fragments of yellowish glass, often with very irregular shape and concave boundaries, such as would arise from the breaking up of pumice.

The coarser accumulations would rather be termed agglomerates. They have a rough and often porous texture, and are largely composed of bomb-like ejectamenta, a quarter or half an inch in diameter, besides pieces of vesicular and pumiceous lava. The interspaces are often partly vacant, with a dusty lining. These agglomeratic rocks are grey or yellowish, but become red or brown by weathering.

Mr. Lister's collection from Falcon Island includes a number of specimens from the ejected blocks of lava scattered over the island. These are more or less vesicular rocks, showing numerous little glassy felspars, one-tenth to one-fifth of an inch long, imbedded in a dark grey ground. Some, perhaps rather weathered, show a lighter grey; while others, more glassy, are black with a silky lustre. The vesicles usually vary from mere pores to cavities an inch or more in length; but in some examples they are drawn out into narrow pipes more than six inches long. The more scoriaceous and cellular varieties are free from porphyritic crystals, and the perfectly glassy pumice is pure white.

These lavas appear to be basic augite-andesites, neither olivine nor rhombic pyroxene being detected. One of the sliced specimens gave a specific gravity 2·436, but this is evidently too low, and indeed the specimen contains numerous microscopic vacuities; a more compact example gave 2·708, which seems to indicate a decidedly basic composition.

In the slices [1264–1266] the porphyritic felspars seem, from their extinction-angles, to be bytownite. They have Carlsbad and albite-twinning, and some of the larger ones show pericline-lamellæ in addition. The crystals are well bounded, but often grouped in clusters so as to interfere with their perfect development. The crystals are clear, but contain glass-cavities, usually with zonal disposition, and some entangled portions of the ground-mass. The augite, pale yellow in section, is not very abundant. Some of the larger crystals are so associated with the porphyritic felspars as to prove that they belong to an early phase of consolidation, but the bulk of the mineral occurs in ill-shaped idiomorphic crystals scattered through the ground. The ground-mass consists of numerous lath-shaped microlites of felspar imbedded with a more or less fluxional arrangement in an isotropic glass. The proportion of glassy base varies considerably, as might be inferred from the appearance in hand-specimens. A very characteristic feature is the occurrence in the mass of well-defined irregular, or usually round, patches of lighter colour and containing less isotropic base than the surrounding mass. These seem to be portions of lava which while partly consolidated became involved in a more fluid magma [1264].

With the exception of the Falcon Island rocks, all those examined

from the Tonga Islands appear to be of submarine formation. The absence or presence in different strata of any sensible proportion of calcareous matter and organic remains is perhaps related to the more or less rapid rate of accumulation at different epochs of eruption. The volcanic material ejected seems to have been almost exclusively of fragmental character, and in some cases there are indications of violent explosive action. This is quite in accord with the andesitic nature of the materials thrown out, which are of types common in the Pacific region. As to the age of the rocks it would be idle to speak until the evidence of their organic contents has been duly set forth, but it would undoubtedly be very rash to refer them all to a Recent age, and some of them may be found to go back far into Tertiary times.

IV.—Note on *Hylonomus Lyelli*, with Photographic Reproduction of Skeleton.

By Sir J. William Dawson, F.R.S., etc.

(PLATE VIII.)

As a sequel to my recent paper on new specimens of *Dendrerpeton*, I have thought it desirable to reproduce by photogravure, for comparison, the type specimen of *Hylonomus Lyelli* now in the collection of the Geological Society of London. The reproduction (Plate VIII.) is of the natural size, though less distinct than in the original. Though the bones are scattered, this specimen enabled me, by measuring the separate bones and adding the cuticular scales found on other specimens, to restore the animal in my "Airbreathers of the Coal Period." [1]

The specimen represented is one of the largest found. Most of the others represent smaller (probably in some cases half-grown) specimens, though not showing any structural differences. It will be noticed that the caudal vertebræ are seen in this example, a fact which I had forgotten when the former paper was written. In the species of *Hylerpeton* and *Fritschia*, though the teeth are different, the development of the limb-bones seems to have been similar. In *Smilerpeton occidentatum* the limbs would seem to have been shorter than in the case of other forms in the erect trees, and the skull long and narrow.

The specimen here delineated, though the bones are scattered, has the advantage of lying on a flat plane of lamination. Some of the thinner bones have, however, scaled off, or have been removed by aqueous infiltration. The cavities left by these have been touched with white so as to bring them out. The difficulty in restoring most of the specimens in the erect trees arises not from the absence of the bones, but from these being scattered through non-laminated material, sometimes soft and crumbling, in other cases hard and arenaceous. In either case it is a work of time and care to uncover the bones, and many of these cannot be reached without risking the

[1] Also on a larger scale in "The Chain of Life in Geological Time."

destruction of others. Some material of this kind representing *Fritschia, Hylerpeton*, etc., is still only in process of development, and may perhaps yet enable their skeletons to be reproduced more perfectly than heretofore.

REFERENCE TO PLATE VIII.

(1) Skull and Maxillæ: (1*a*) Sternal and Scapular bones; (2) Mandible; (3) Humerus, Ribs and Vertebræ; (4) Hind Limb; (5) Pelvis; (6) Caudal Vertebræ.

V.—NOTE ON THE ALLEGED GENESIS OF RUTILE IN FIRECLAYS.

By Major-General C. A. MACMAHON, F.G.S.

MR. W. M. HUTCHINGS' "Notes on the Fireclays of the Coal-measures," published in the April Number of the GEOL. MAG., contains many interesting facts and suggestions on which I should like to offer a few remarks.

The conclusion at which the author appears to have arrived (see para. 2, p. 168, read with the two bottom paras. of that page) is that the formation of the "rutiliferous mica," and its contained rutile, is due to dynamo-metamorphism.

This is rather a startling conclusion and it is one which seems to rest on slender evidence. Even if it could be proved that the rutiliferous mica and the free rutile-needles are both of secondary origin, no evidence has been adduced to show that their genesis is due to dynamic and not to ordinary aqueous agencies. Evidence on this point is the more desirable as one does not usually associate beds of unindurated clay with the display of dynamic energy. Do fossils of these Coal-measures exhibit pressure deformation?

Even in cases where sedimentary rocks have evidently suffered deformation from earth-movements, it would not be safe to assume, without proof, that the secondary minerals found in them owe their birth to dynamic causes.

With respect to the Seaton beds there are two distinct issues to be proved. Are the rutile-needles and the yellow mica of secondary or of clastic origin? And if secondary, to what process do they owe their birth?

Regarding the first issue I remark that some of the author's facts seem quite consistent with the view that the rutiliferous mica, and the free rutile-nodules, were transported to the spot along with the other constituents of the clay. The finest washings "A, B, C," contain "far away the largest portion of the rutile-needles;" and many of the quartz and felspar grains carry "more or less a skin of rutiliferous 'paste' in spite of all the washing and agitation. I think it is," Mr. Hutchings adds, "really corroded on to the substance of the grains in many cases." These facts do not give much support to the theory that the mica and its endogenous rutile "is a new formation posterior to sedimentation."

Another fact mentioned by the author seems to point to the same conclusion: he tells us that the flakes of rutiliferous mica, with few exceptions, are seen by their extinctions to be "aggregates of more or less numerous smaller flakes overlapping one another, and with

different optical orientation." If, as I understand, the orientation is promiscuous, this fact seems to point to the deposition of the flakes one above the other by water—ordinary sedimentation—rather than to crystallization *in sitû*. As the molecules of crystals possess strong polarity, the molecules of mica would, at the moment of crystallization, surely have followed the laws of crystallization and have arranged themselves in definite order either as simple or as twinned crystals. If, on the other hand, these "complex flakes" are the mere promiscuous agglomerations of numerous separate individuals, and not single crystals, I fail to see how the fact of this agglomeration supports the contention that the "rutiliferous mica" is a secondary mineral formed after the deposit of the clay. Finely divided fragments of mica suspended in water would be very likely to come together as mechanically mixed agglomerates even before they sank to the bottom. This process, I suspect, is probably responsible for Mr. Hutchings' "globular aggregates in which the mica lies in all azimuths." The attraction which minute particles suspended in water exercise on each other may be observed in a chemist's test-tube every day.

The author in his examination of the mud prepared in the Laboratory from the fireclay observed an upward and a downward limit in the size of the flakes of rutiliferous mica, and he attaches considerable importance to the fact. "Looking at the facts stated," he writes at p. 167, "the one that appears to have most bearing on the main point concerned is the pretty strict upward limit of size of the rutiliferous flakes." Mr. Hutchings' contention is that the genesis of the rutiliferous mica, and the rutile contained in it, is due to dynamo-metamorphism "posterior to sedimentation" (p. 168), and as the fact stated above seems to be "the main point concerned," it is worth while to consider it in some detail.

In the first place I would ask whether we can be quite sure that the fact relied on is not in some way due to the process of "fractional levigation" employed. Mr. Hutchings' process involved the crushing of dried clay to powder and subsequent crushing in a mortar with water, followed by repeated washings. After such dynamic treatment, I doubt the value of any theory, as to the origin of the rutile, based on the size of the mica flakes that were finally found to contain rutile compared with the size of the flakes in which this mineral was absent. Free rutile flakes appear to be more abundant (p. 165, para. 2) than those included in mica; and the author tells us, at p. 166, that "the rutile lies mainly in between the minute component flakelets, and is set free when these are detached." And as Mr. Hutchings' contention is that the rutiliferous mica is a secondary product formed subsequent to the deposition of the clay, it follows logically that the free rutile-needles were detached from the mica in Mr. Hutchings' laboratory under the gentle persuasion of his pestle and mortar.

Considering the rough treatment the mica received in the laboratory or during its previous transport by river, and considering the fact that the bulk of the rutile-needles (p. 165) were free and

detached from mica flakes, it does not seem remarkable to me that the larger flakes should have been landed on the stage of the author's microscope minus their rutile-needles. The flakes of rutiliferous mica appear to have been below $\frac{1}{1000}$th of an inch in diameter, and owing to their extreme microscopic size may have been protected from abrasion by their superior powers of flotation.

If mica, as Mr. Hutchings seems to think, was the mother of the rutile, we can hardly suppose that *all* the mica transported to the Seaton beds was sufficiently rich in titanic acid to furnish the titanium dioxide for the rutile. The titaniferous mica was probably only one of several species of mica transported to Seaton; and if so, each species may have been characterized by a size of flake peculiar to itself. But apart from the question of habit, differences in the size of the flakes may have resulted from another cause. Mr. Hutchings found three species in his fireclay; muscovite, biotite, and a yellow to green species containing rutile-needles. No evidence has been adduced to show that all three species came from the same parent rock. They may, therefore, have come from different areas, and the differences observed in the size of the flakes may be the measure of the distances travelled by the different species.

The circumstance that rutile-needles were not found in the muscovite or in the biotite may be owing to the fact that these micas do not contain sufficient titanium dioxide; and I fail to see what bearing the absence of rutile from the muscovite and biotite has on the points at issue, viz. whether the rutile and the yellow mica are of clastic or secondary origin, and if secondary, whether their genesis is due to ordinary aqueous or to dynamic agencies.

If, for sake of argument, we admit that the rutile is of secondary origin, can we be sure that any of the species of mica found in the fireclay was the mother of the rutile? Without disputing Roth's conclusion that the "separation of the titanic acid of weathered micas as rutile is often enough observed," it seems desirable to call attention to the fact stated by Mr. Hutchings that "micaceous ilmenite" is "rather abundant" in his fireclay. May not this mineral have supplied the titanic acid for the rutile? The fact that some of the needles of rutile are found between the mica "flakelets" does not negative this suggestion, because capillary action is a potent factor in such cases. There is no evidence in Mr. Hutchings' paper to show that any of the mica of the fireclay contains titanic acid, whereas we know that ilmenite contains a large amount—sometimes as much as 59 per cent.—of titanium dioxide.

Lastly, I would suggest that if the yellow species of mica and the rutile are really secondary minerals, they are products of ordinary aqueous action. I think it will probably be admitted that the fireclay of the Coal-measures was laid down in water. If so, the soft mud of which it was originally composed must have contained much interstitial water. What has become of this water? May we not assume that much of it was used up in chemical action on the finely triturated minerals of which the solid portion of the mud was composed? The water, unless it differed from all other river and

sea-water of which we have knowledge, must have contained free oxygen, carbonic acid, and other potent chemical reagents. Are we to believe that these active reagents sat still and did nothing for thousands upon thousands of years until at the end of æons dynamic metamorphism, like a muscular pedagogue with a long birch, came to warm them into action?

VI.—Post-Pliocene Continental Subsidence (in America) *versus* Glacial Dams.

By J. W. Spencer, M.A., Ph.D., F.G.S. L. and A.

THE growing interest in the evolution of the Continent now calls for more accurate information than formerly regarding the changes of level of land and sea in recent geological times. The amount of these oscillations was one of the most important factors in the investigation of the "Building of the Great Lakes." Hence the study of the history of the lakes has contributed to our knowledge of the changing relations of the continent and the sea.

From a study of the submerged channels along the American coast, it has been shown that the continent was greatly elevated during some epoch or epochs intervening between the middle Miocene and the early Pleistocene periods.[1] The elevation of the land was over three thousand feet higher than now, and probably reached for a short time to over five thousand feet.

The elevated condition of the continent was followed by a depression of the land to far below the present altitude, before the upward movement restored the now existing conditions. There may have been more than one episode of elevation and depression; but the problem that we seek to answer is: What was the maximum depression of the later Pleistocene times, after the great beds of boulder clay were formed? for the great elevation was shortly before that epoch.

Most geologists are ready to accept the high continental elevation, but there are differences of opinion respecting the amount of the subsidence. Although many have their own views upon this subject, few serious attempts have been made to solve the problem unbiassed by theory.

We must seek for the evidence of the late regional elevation in the remains of old shore-lines, such as beaches, terraces and sea-cliffs, which are more or less disturbed and obliterated. Isolated remnants of beaches are not accepted by all as proof of a recent elevation, although found at high altitudes, but the beaches often contain the direct proof of their own elevation.

No better example is found than the Iroquois Beach of the Ontario Basin. This elevated shore-line is one of the youngest and best preserved in the Great Lake region. It rests upon the youngest "till" deposits. Since its formation it has been warped towards the north-east, and thus at Fine, north of the Adirondack Mountains, it

[1] "High Continental Elevation preceding the Pleistocene Period (in America)," by J. W. Spencer, Geol. Mag. Decade III. Vol. VII. 1890, p. 208.

has been lifted over 600 feet above its own elevation at the head of Lake Ontario.[1] By another series of deformed shore-lines,[2] it has been found that the Iroquois Beach at the head of the lake has been lifted its own height above the sea. Hence there is measured proof that the northern side of the Adirondacks has been recently elevated a thousand feet, or that it was recently a thousand feet lower than now. The initial point of this movement was near the head of Lake Michigan. Its maximum deformation occurs in the Adirondacks, and amounts to six feet per mile. Whether this rise continues to the Atlantic, or is transformed into a depression, or is faulted east of the mountains, remains a question to be determined. Only fragments need be looked for east of the region already explored, for the deserted shore has been traced into a region of broken mountains and wilderness.

Three hundred feet above the Iroquois plain the Algonquin Beach of the Huron basins is located.[3] In it there is a similar deformation to that recorded in the Iroquois shore, but the initial point of the warping is beyond the head of Lake Michigan. With the deformation continuing to the north-east, it would appear that the Laurentian Mountains north of the Great Lakes were very much depressed during the Algonquin episode. The evidence of the formation of the Algonquin Beach at sea-level has already been collected.[4]

Whilst there is great deformation recorded in the higher beaches, the surveys of these more broken geological records do not enable us to trace the shore-lines down to sea-level, as in the case of the Iroquois, and to nearly as perfect an extent, the Algonquin Beach. Consequently, it is necessary to rely more fully upon the perfection of the structure of the deserted shores, and upon their positions, which would preclude their formation in confined lakes. Such conditions exist in Ontario, Michigan, and Ohio, where extensive surveys have been made.

The lower of these shores, as the Ridgeway Beach,[5] like those before named, were formed about bodies of water which opened only to the north or east. But ascending a little higher, the Maumee Beach[6] occurs at altitudes which permitted its formation in water having free communication with the Ohio and Mississippi valleys by two depressions. Above this plain there are higher gravel terraces and plains in Michigan, and elsewhere, notably those between Kalamazoo and Marshall, with an elevation of a little more than 900 feet above the sea. From them the country falls away by steps towards the lakes; but the sheet of water which they once bounded had at least five connexions with the drainage

[1] "The Deformation of Iroquois Beach and Birth of Lake Ontario," by J. W. Spencer, Amer. Journ. Sci. vol. xl. 1880, pp. 443–451.

[2] *Ibid.* p. 447.

[3] "Deformation of the Algonquin Beach and Birth of Lake Huron," by J. W. Spencer, Amer. Journ. Sci. vol. xli. 1891, pp. 12–21.

[4] *Ibid.* p. 21.

[5] "High Level Shores in the Region of the Great Lakes and their Deformation," by J. W. Spencer, Amer. Journ. Sci. vol. xli. 1891.

[6] *Ibid.*

of the Mississippi system.[1] Other higher terraces about more insular points are found in the same region, and farther north in Michigan they are said to occur at the summit of the highest land east of Grand Traverse Bay at 1682 feet above tide.

In Ontario there are well-marked sea-cliffs carved out of the Niagara escarpment, as westward of Collingwood, especially at elevations of from 1200 to 1425 feet above the sea. At various intervals, between the plain of the Algonquin Beach and the highest land of the peninsula—1709 feet—there are also terrace and beach deposits moulded out of the drift. These remnants of shores are seen to within 20 feet of the highest point of land. The shore-markings of these elevated lands are rendered more certain by the perfectly water-worn stones, and the extent of the beach and terrace structure. The sea-cliffs are too deeply graven to represent evanescent coast-lines. But all of these records are interrupted owing to the topography of the country, erosion by atmospheric agencies, and the recent Pleistocene deformation of the region.

Some of the positions of the surveyed coast-lines have been mapped; for a detailed list of localities reference should be made to "High Level Shores in the Region of the Great Lakes, and their Deformation."

Again, at Dog Lake, north of Lake Superior, Professor H. Y. Hind observed terraces at 1425 feet above the sea.[2]

After allowing for all the measurable Pleistocene and recent deformation of the region, these elevated shores stand out so high above every natural barrier, even far away to the south as well as to the north, that their occurrence demands explanation by other than local causes.

The highlands of the Ontario peninsula do not form Nilometers reaching more than 1700 feet above the sea; but in Potter County, Western Pennsylvania, 100 miles south of Lake Ontario, they develope a watershed reaching to 2680 feet above tide, with the Genesee river flowing north to Lake Ontario; the Alleghany to the Ohio river; and Pine Creek to the Susquehanna. About the highest flattened knob, of only a few acres in extent, and rising to within twenty feet of its summit, there is a ridge of small, well water-worn gravel, nearly free from sand. Mr. Carvell Lewis speaks of it as kame-like,[3] but its structure and form is not different from that which may be true beach. This is emphasized by the occurrence of a zone of boulders forming a pavement a few feet below the gravel ridge—a feature so commonly developed in front of the deserted beaches of the Lake region. This gravel ridge rests upon the highest point of land at the very front of the "terminal moraine" of Mr. Lewis, with the land declining to the north, as well as falling away to the south. These gravels form a superior deposit resting upon "till" charged with angular shingle of local

[1] Cited before.

[2] "Assiniboine and Saskatchewan Expedition," 1859, p. 120.

[3] "A Terminal Moraine," by H. C. Lewis, Geol. Survey Pennsylvania, Rept. Z, p. 143.

Carboniferous sandstones, and it is out of this material that the pebbles were formed.

There are similar superficial gravels on other, but, of course, inferior knobs along the very foremost portions of the "terminal moraine." But the drainage from these ridges is to the north, and Mr. Lewis emphasized the fact that there is no drift in the small streams flowing to the south. The theoretical importance of this observation will be noted later.

Besides these highest of all the superficial gravels, south of the Great Lakes, which I have examined, I have also visited the high terraces of the Genesee River flowing northward from the deposits just described. Here several pauses in the receding waters are recorded. These are notable from an elevation of 1900 feet downward. At this named high altitude the valley is nearly a mile wide, and now 250 feet below the terrace. Our knowledge of these elevated and disconnected water deposits is yet very scanty, but certainly very suggestive, when supplementing the surveys of the lower coast-markings in the lake region.

A very interesting terrace remains in a valley three or four miles to the east of Horseheads, New York. The altitude of the terrace is 1200 feet above tide, whilst the gravel-covered floor of the valley, at Horseheads, is only 900 feet. This last valley is over a mile wide, and is that connecting the trough of Seneca Lake with the Susquehanna Valley.

Similar elevated terraces have been noted by Prof. I. C. White along the higher Potomac Valley facing the Atlantic, and along the adjacent tributaries of the Monagahela, which drains to the westward. These deposits he notes up to an elevation of 1675 feet above the sea, and 175 feet above the valley, along a tributary creek above St. George, W. Va.[1]

At Nachvak, in Labrador, Dr. Robert Bell found beaches of great distinctness at 1500 feet above the sea. Gravel and shingle terraces were also found to an estimated height of 2000 feet.[2]

It has already been noted that the differential rise of the Iroquois Beach, north of the Adirondack Mountains, amounts to six feet per mile, and that it has there been lifted to a thousand feet. If this rise continue to the White Mountains, then the equivalent of the Iroquois Beach may be found amongst the terraces of the high valleys in that region. Its records may be preserved still further north-east, on the drift-covered sides of Mount Katahdin, in Maine. Mount Desert, on the coast of Maine, rises to 1500 feet,[3] and shows remnants of coast action to its summit (Shaler); consequently, it is too low to bear records of the Iroquois shore, unless the warping at the earth's crust becomes one of depression east of the Adirondacks.

In Ontario, some of the high shores, referred to above, occur at

[1] "Rounded Boulders at High Altitudes," by I. C. White, Amer. Journ. Sc. vol. xxxviii. 1887.

[2] Rept. Geol. Surv. Canada, 1885, DD, p. 8, and Bull. Geol. Soc. Amer. vol. i. p. 308.

[3] "Geol. Mount Desert," by N. S. Shaler, Rept. United States Geol. Survey, 1888, p. 993.

elevations of a thousand feet above the Iroquois plain; therefore their equivalents in the northern Adirondacks should be looked for at about 2000 feet above tide. The beaches reported in Vermont by Prof. Hitchcock,[1] at or below 2300 feet, doubtless correspond to some high shore-lines of the Ontario peninsula. Upon the same basis, these high beaches should be looked for at 3000 feet in the White Mountains, and at greater elevation on Mount Katahdin, in Maine.

If we regard the gravels of the highlands of Pennsylvania as having been formed at sea-level, then it would be reasonable to look for their counterpart at elevations of over 4000 feet on Mount Washington, in New Hampshire, and to the summit of the drift (4400 feet) on Mount Katahdin. These conjectural estimates, based upon a possible uniformity, may aid in the correlation of the topographic features of the mountain region of the east and of the lake region.

As far as relates to the north-eastern portion of the continent, our observations on Neptunian phenomena have now been epitomized. An explanation is necessary. That the pebbles of the beaches and the shore-lines were the results of wave or current action no one questions, but there are differences of opinion as to the conditions under which the waters moulded their coast-lines. Were these deserted shores constructed at sea-level, or were they moulded in glacial lakes? These are the theoretical questions before us.

The difficulties which the sea-level theory present to some minds may be stated to be—(*a*) a great regional depression of the continent; (*b*) the absence of absolute continuity of the beaches; (*c*) the absence of marine organisms in the beaches; and (*d*) the personal equation of theoretical views. On the other hand, the theory of glacial dams presents such obstacles that their value will be considered at length.

The idea of the hydrostatic stability of the continent must not be too strongly relied upon, for the evidence adduced, showing that the continent lately stood three, or even temporarily at six thousand feet higher than now, appears conclusive. Such mobility of the earth's crust being established, there appears no reason why the terrestrial pendulum could not have moved equally in the opposite direction, and carried down the highlands of Pennsylvania to nearly three thousand feet, or those of New England to twice this depth. The objections to such subsidence could only be based upon its magnitude, which observations must settle.

The absence of the continuity of the shore-markings is an objection only to a limited extent. Part of the reported absence arises from the imperfections in the explorations, owing to their changing character; the local non-formation of beaches, as described in a previous paper;[2] the failure of identification of separated

[1] Geology of Vermont.

[2] "Ancient Shores, Boulder Pavements, and High-level Gravel Deposits in the Region of the Great Lakes," by J. W. Spencer, Bull. Geol. Soc. Amer. vol. ii. 1889, pp. 77.

points, owing to subsequent terrestrial deformation; and the interruptions occasioned by topographic features and subsequent obliteration by erosion. All of these difficulties are greatest in the higher regions, for there the beaches must be looked for amongst islands and detached mountain knobs.

The absence of marine remains seems perhaps the greatest obstacle to the acceptance of a sea-level formation of the beaches, as marine organisms are found only up to 520 feet.[1] But the Pleistocene gravels occur in Georgia and Alabama, in positions facing the sea, at altitudes of 700 or 800 feet, and higher up the greater valleys at 1500 feet,[2] without their containing any marine remains. Even where marine Pleistocene beaches occur on the coast of Norway, there are very few localities where shells are found. How many of the older geological formations are unfossiliferous? How many of those ancient beach deposits now represented by conglomerates, porous sandstones, and, indeed, many clays, are entirely barren? Under such conditions have we a right to pronounce judgment on the freshness of waters based on the absence of aqueous organic remains? This question will be referred to again in considering the glacial dam theory.

As to the personal equation, it ought not to pass beyond the limit of conservatism into the province of obstruction: but it is quite proper that it should be considered; for, as Prof. Geikie has said, when controversy ceases, the interest in the investigation declines.

Glacial lakes are of two kinds, those whose waters are retained by morainic barriers, and others sustained by ice barriers alone.

The former class is represented in several valleys in the Alps, where lateral glaciers enter and cross greater valleys; sometimes the glacier carries its lateral moraine across the valley, and builds a more or less permanent earth dam. Such lakes remain long after the glacier has melted away, and, even when drained, show evidence of their origin. A consideration of this class of glacial lakes does not enter into the subject of this paper.

In Switzerland, Greenland, and Alaska, other glacial dams are now well known. These are retained by the ice alone. When glaciers, free from morainic materials, descend lateral valleys, and cross other valleys, they do not obstruct the river, for it continues to flow beneath the ice. However, there are many places where glacial lakes occur between the ice and the sides of the valleys; especially is this the case where two glaciers meet at the end of a mountain spur, like Lac Tacul in Switzerland. Small glacial lakes sometimes occur where lateral valleys unite with the glacial-filled channel, like the Marjelen See. All modern glacial lakes are of small size. One of the largest lakes described in Greenland is not over three or four miles long, and a mile wide.[3]

Such lakes, when they exist above sea-level, are evanescent. Mr. H. Topham described some glacial lakes of Alaska which discharge by a tunnel eight miles long, under 500 feet of ice.[4] Mr. I. C.

[1] At Montreal.
[2] On the Upper Etowah River of Georgia.
[3] Medellelser om Groenland.
[4] Proc. Roy. Geogr. Soc. 1888, p. 424.

Russel makes similar reports. The out-flowing waters enlarge the tunnels, thereby draining lakes; but the ice-roofs fall in, and by the accumulation of ice blocks the tunnel becomes temporarily obstructed, causing the water of the lakes to rise. In the very nature of the case, large lakes could not be expected, for the conditions which would permit their formation would cause the glaciers to recede. Especially would this be the case if the glaciers were hundreds of feet above the sea, with rivers draining beneath or through them. It would be difficult to perceive how any water-level could be maintained long enough to permit the waves to carve out terraces and sea-cliffs. With glaciers coming down into the sea, it is easy to understand how bays and inlets could be obstructed by the ice so as to allow the water to be freshened. In such lakes the water-level would be maintained long enough to leave inscriptions in the form of terraces and beaches.

Such is a brief account of the natural history of glacial dams. It has been said that the easiest explanation of the theory of our great lakes is by regarding them as formerly great glacial dams. So it was thought ten years ago, that the least troublesome hypothesis of the origin of the great lake basins was by their excavation by glaciers; but the writer, going into a field of investigation, almost sealed by pre-judgment, has shown that glaciers did not scoop out the basins, and has otherwise found satisfactory explanation of their origin,[1] without invoking the necessity of ice being converted into rock diggers. So also the evidence of glacial dams has not been found as far as my observations have been extended.

Let us examine how the glacial dam theory applies to the shore-lines already described.

The physical features of the Ontario basin are the most favourable for the construction of a great lake retained by glacial dams. As proved by its deformation, the Iroquois beach was formed at sea-level. If this proof of the altitude of its birthplace did not exist, the evidence of its elevation would be obtained from a consideration of the ability of glaciers to close the St. Lawrence valley to the north-east. Such a barrier would have been from 80 to 100 miles wide, and from 800 to 1300 feet deep (below surface of water) according to location. Yet the drainage of the then expanded lake, over 300 miles long (as far as surveyed) and 100 miles or more in width, was against, into, or under the supposed glaciers, except to a limited extent in its earliest stages, when a partial overflow was by the Mohawk Valley. Had the lake been above sea-level, a river as large as the St. Lawrence would soon have eaten its way through the ice, and lowered the lake, for in that direction alone it had to flow; consequently, the great cut terraces and beaches requiring centuries or millenniums of time, could not have been formed except at sea-level.

If the Algonquin Beach of the Upper Lakes were formed in a glacial lake, then the ice barrier in the region of Lake Nipissing

[1] "Origin of the Basin of the Great Lakes of America," by J. W. Spencer, Quart. Journ. Geol. Soc. Lond. vol. xlvi. p. 523.

would have been 600 or 700 feet beneath the surface of the water. The drainage must have been under the ice, and have amounted to a discharge equal to that of the modern Detroit River, as the drainage of Lake Superior, Lake Michigan, and Lake Huron basins would have been thus borne seaward, descending 300 feet to the level of the Iroquois water. Under such conditions, the question may be asked, how could the lake surface be retained long enough at any level to carve out the deeply-graven water-lines and terrace-plains of the Algonquin Beach, in place of the discharging waters melting away the icy barriers, which were supposed to have been the means of retaining the lake 300 feet above the level of the Iroquois waters?

We now rise to the shores which bounded the Warren water. These have been explored from Lake Michigan to New York, and to north-east of Toronto, upon the Ontario peninsula. Upon the glacial dam theory, this sheet of water would need a barrier to the north as well as to the east. The drainage of the lake, at all stages from the Ridgeway Beach downward, was to the north-east, and beneath a greater mass of ice than in the case of the Algonquin or the Iroquois water. But above the Ridgeway Beach,[1] at the Maumee level,[2] there were outlets across Ohio and Illinois, if it were a lake. The difficulties are increasing.

The shore markings occurring near Kalamazoo, at about 900 feet above tide, represent a sheet of water having at least five outlets across Ohio and Illinois.

Again, the sea-cliffs of the Ontario peninsula, at from 1200 to 1425 feet and more, and the beaches now found up to 1689 feet, would demand great dams to the south as well as to the north. But such dams could scarcely have existed, with open waters carving out sea-cliffs and terraces on the high peninsula of Ontario, and also leaving records, 200 miles to the south. It should be noted that gravel deposits of the so-called *kame* and *ôsar* structures occur at all high levels, but of these I do not take cognizance.

The drainage of this high country, such as the Genesee valley, with terraces up to 1900 feet or more, and of the "terminal moraine" up to 2680 feet, was toward the north without obstruction.

Ascending now to Potter County, we find the gravel ridge at 2660 feet, on the very edge of the highest knob of the "terminal moraine." This high point could not have stood out of the ice as a Greenland *Nunatak*, with a lake around it, for it is at the margin of the drift, and glaciers do not deposit their terminal detritus within the ice, but at their very margins. It seems impossible to conceive a glacial mass retaining a lake about this flattened knob, even if the country were submerged to almost sea-level.

There are other similar deposits on adjacent summits. Again, had a glacier existed on the top, or on the southern side of this "moraine" ridge, its melting ice must have carried great quantities of drift into the valleys to the south, which neither Mr. Lewis nor

[1] "High Level Shores in the Region of the Great Lakes and their Deformation," by J. W. Spencer, Amer. Journ. Sci. vol. xli. 1891. [2] *Ibid.*

I have seen. But the drainage was to the north, into the hypothetical glacier, which, if it permitted subglacial drainage, could scarcely have formed lakes.

Under these conditions fairly stated, I think, whether is it easier to accept a great subsidence of the continent to nearly 2700 feet, in Western Pennsylvania, or account for the phenomena by glacial dams, formed on land, vastly lower to the north.

Indeed, the great deformation of the lake region had scarcely begun, and consequently even the modern highlands, north of the great lakes, were then very much lower than now, when compared with the region to the south. I cannot hesitate in forming a conclusion that the evidence is in favour of a late continental subsidence, rather than of hypothetical glacial lakes, hundreds of miles long and broad, like nothing ever seen, which could not answer the requirements.

The difficulty in accepting the subsidence without the occurrence of marine shells has in part been pointed out. But their absence in the lower beaches may be accounted for, in part, by the sheets of water being more or less cut off from the sea, and receiving great quantities of fresh water. This, however, will not explain their absence on the higher beaches. The varying climatic conditions of the water, and the changes of level, destroying the life, and too rapid to allow of remigration, may in part account for the absence of organisms in the shore-lines.

The record of subsidence deciphered in the high shore-lines of the lake region is supported by the observations of Dr. G. M. Dawson, Mr. R. G. McConnell, and others, on the mountains rising above the great plains of North-Western Canada, and on the mountains between there and the Pacific Coast. Dr. Dawson[1] finds gravel terraces upon high sides of the Rocky Mountains facing the east, in position showing their origin not to have been river-terraces.

From extensive observations Dr. Dawson concludes that the Pleistocene submergences amounted to 4000 or 5000 feet in the region of the International Boundary (49th parallel), whilst in Alaska it did not exceed 2500 or 3000 feet. He also hypothecates two episodes of submergence, the latter being less extensive than the former. Further, he regards the elevation and subsidence of the great plains and western mountains as alternating, and that the drift materials of the plains were deposited at sea-level.

Mr. R. G. McConnell informs us that on Cypress Hills, with an altitude of 4800 feet, the drift does not rise above 4400 feet. A hundred and fifty miles to the north-west the drift is not found above 3400 feet on Hand Hills (Tyrrell). But south of the Cypress Hills, near the 47th parallel, drift occurs up to 4660 feet on Three Buttes (Dawson). From these figures Mr. McConnell shows a differential level of 7·2 feet per mile, the elevation being greater nearer the 49th parallel.[2]

[1] "Later Physiographical Geology of the Rocky Mountain Region in Canada, with Special Reference to Changes in the Elevation and the History of the Glacial Period," Trans. Roy. Soc. Canada, 1890.

[2] Geological Survey of Canada, Report for 1885.

In the east, the history of the changes has not been fully deciphered. Erratics occur on the top of Mount Washington to 6300 feet, whilst on the top of Mount Katahdin, in Maine, they occur to only 4400 feet (Upham). Conforming with Dr. Dawson's views, as applied to the west, we have a greater rise in the White Mountains than eastward. The altitude of beach formation in the highlands of Labrador (1500 to 2000 feet) shows the recent uplift to have been less than in New England.

Combining the movements of the east and the west, it would appear that the great Pleistocene uplift reached its maximum along a line between the Gulf of the St. Lawrence and Vancouver Island, rather than in higher latitudes. The youthfulness of the northern topographic features shows that the elevation of the lands in the higher latitudes, above the base-level of river-erosion, has taken place in recent geological times; for there is a lack of such great cañons in the country to the north of the great lake zone, as occur in the region to the south of it.

If the subsidence of the northern portion of the continent appears to have been great, that of Barbadoes to the south-east appears to have been greater, for Messrs. J. B. Harrington and A. J. Jukes-Browne,[1] have pointed out that there are on the island oceanic deposits resting upon beds of sandstones and shales of probable Miocene age, and beneath coral formations of age not greater than the Pleistocene. These deposits indicate an origin of not less than a thousand fathoms, and, as Mr. Jukes-Browne points out, probably of vastly greater depth. This geologically recent subsidence was likely to have been synchronous with that of the north, but may have been one of those alternating conditions hypothecated by Dr. Dawson.

The fjords of the coast of Norway show that the Scandinavian peninsula stood 4000 feet higher than now. The silts and terrace deposits at 3000[2] feet point to a subsidence of that region, the same as similar deposits in the mountains of America.

The deep submerged channels south of Asia, like that of the Ganges, which is 3570[3] feet deep, point to a recent submergence to that amount. But such deep channels are not known in the north of Asia, consequently the higher latitudes do not show a great amount of recent depression. The Pliocene deposits of Sicily, at 3000 feet, demonstrate a recent elevation.

Pliocene deposits in the south-east of England are now found at 600 feet above tide. Their counterparts at Utrecht have been shown by Mr. Clement Reid to be now submerged more than 1143 feet.[4]

The oft-quoted Moel Tryfaen deposits, in north-western Wales, contain marine shells at 1400 feet, with similar but unfossiliferous beds rising to nearly 2000 feet. These deposits, which I have visited, I consider to have been formed where found. But they do

[1] Geology of Barbadoes, 1890.
[2] "High-Level Terraces of Norway," by J. R. Dakyns, GEOL. MAG. 1877, p. 72.
[3] Brit. Admiralty Chart, No. 70.
[4] "Nature," August 12, 1886, p. 342.

not represent so late a subsidence as our deposits in the lake region, for they are not the superficial gravel, but are covered by a few feet of more recent till.

These few foreign examples, just cited, show that the continental movements, as set forth in this paper, are not peculiar to America, but they were probably not synchronous, although they have taken place in the most recent geological times.

This paper must of necessity be imperfect, as it is the first attempt to work out the detailed evidence of recent terrestrial subsidence from records in the ancient shore-lines, many of which have only lately been reported. All of the phenomena cited show that in modern geological times there have been gigantic movements causing the earth's crust to move to and fro, producing conditions which have greatly modified the physical features, climatic conditions, and distribution of life.

VII.—The Effect of Sedimentation on the Temperature of the Earth's Crust.

By T. Mellard Reade, C.E., F.G.S., etc.

MY letter in the March Number of the Geological Magazine, asking for a description of the "Herschel-Babbage" theory of Mountain formation, appears to have called forth Mr. Davison's "Note on the Expansion Theory of Mountain Evolution,"[1] in which he favours us with his definition of the "fundamental principle of the theory of terrestrial evolution which has sometimes been called the 'expansion theory.'"

Whether this fundamental conception is identical with the "Herschel-Babbage" theory is not stated, but I am obliged to Mr. Davison for putting his views on the subject into a form admitting of examination and discussion. To make my meaning plain, I shall have to repeat Mr. Davison's own words.

"Masses of sediment laid down in an area of subsidence are gradually lowered to regions of the earth's crust that are at a higher temperature than that in which they were deposited. The sediment, being heated, expands, is crumpled and folded internally, and, bulging up at the surface, is reduced by denudation to the form of a mountain-chain."[2] On which the following observations are made. "It is obvious that the heat which passes into and expands the sediment must be withdrawn from the immediately adjoining parts of the earth's crust, partly laterally, but chiefly from below; and that the amount of heat gained by the sediment must be equal to that lost by the crust."

So far from this being "obvious," I consider it a fundamental misconception. If a mass of strata at the surface having the surface temperature could be placed in contact with another mass, say ten miles deep, having the temperature due to that depth, the colder

[1] Geological Magazine, May, 1891, p. 210.

[2] It is unnecessary for me to criticize this "fundamental" definition further than to disclaim it as an adequate statement of my own theory. For an outline of this I must refer those interested to the forthcoming June number of the Philosophical Magazine.

rock would withdraw part of the heat from the hotter till an equality of temperature was reached. But this is not what takes place; the subsiding rock does not come into contact with strata at a higher temperature.

So far from heat being withdrawn laterally and from below, the general outflow of heat is checked in the areas where sediments are being laid down. In these areas the sphere is losing *less* heat than where the surface continues in a normal condition. A portion of the heat that would otherwise escape into space is being used up in heating the sediment.

Mr. Davison seems to have had a glimmering of this truth before completing his "Note," for the last paragraph but one is entirely opposite and contradictory to the preceding which I have quoted.

Unfortunately the effect has not been to compel him to withdraw the erroneous view, but to attempt to minimize the dynamical effect of the true one. Having dealt pretty freely with the quantitative problems in my "Origin of Mountain Ranges," I do not propose to enter upon this phase here.

To say that the sediment piled up in an earth trough "*withdraws*" heat from the underlying strata is about as correct as to maintain that covering a steam-boiler with felt withdraws heat from it. To give an illustration; if the valley of the Dead Sea were levelled up with sediment, the underlying rocks would be raised to a temperature dependent upon the thickness of the sediment and its coefficient of conductivity. The raising of the temperature of a body is not usually considered to indicate a withdrawal of its heat.

VIII.—On the Preparation of a Cheap Heavy Liquid, for the Separation of Minerals.

By W. B. D. Edwards, A.R.C.S.,
of the Geological Survey of India.

THE high price of all heavy liquids, and the consequent care that has to be taken in using them, the latter of course entailing great expenditure of time, were the reasons which caused me to make experiments, with regard to the manufacture of Klein's solution (borotungstate of cadmium) on a small scale. The price quoted in a well-known chemical manufacturer's price-list is 3*s.* 6*d.* per oz. My experiments have shown me that it can be made for about 7*d.* per oz., plus the value of the time of the maker. The process is very simple, and not much time is necessary in making it. A rough outline of the method of preparation is given by Dr. Klein in the Comptes Rendus, vol. xciii. August, 1881.

The apparatus required consists of two large porcelain evaporating dishes 10′ diameter, two of 6′, and two of 3′, two glass beakers 10′ deep, and two 6′ deep, a glass funnel and a water bath. A fume cupboard or some arrangement for carrying off acid fumes is also necessary. The following weights given will make 160 grains of cadmium borotungstate (*i.e.* about 50 c.c.), and can be conveniently manipulated in vessels of the size given above.

Dissolve 450 grams of crystallized sodium tungstate in as little boiling water as possible. When quite dissolved, add 675 grams of boric acid in small crystals, a little at a time, and with constant stirring. This should be done in a large beaker.

When quite dissolved, the solution should be poured into a large evaporating dish and put aside in a place where it will not be disturbed or shaken. It should be covered up from dust. In about twenty-four hours, or longer, the liquid, which is of a light purple colour, should be poured off quickly into another evaporating basin from the crystals. The latter should be in the form of a hard solid deposit at the bottom of the basin. These crystals can be washed with hot water three or four times, the washings being added to the mother-liquor.

The latter will now probably be found to be in a thick pasty condition, due to the formation of small crystals. These will be found to dissolve up on heating the dish and its contents on a water bath. About half of the water can now be driven off on the water bath, care being taken not to drive off so much that a crust begins to form on the surface of the hot liquid. The solution is again set aside as before and left to cool and crystallize. The liquid is poured off into one of the smaller dishes and the crystals washed as before. This process of crystallization is gone through again until a piece of orthoclase will float in the liquid. The principal point being to always make the polyborates of soda crystallize out either as single large crystals or as a hard crystalline crust. It is impossible to separate and wash the crystals if they are very small.

Owing to the high density of the liquid, in the later stages a longer time is necessary for the sodium borates to crystallize out than at first. A piece of glass or felspar will be found to float when the liquid has been evaporated down to about 220 c.c. The next process is to heat the sodium borotungstate on the water bath to 100° C.; pour into a large beaker, and add a boiling saturated solution of barium chloride. This should be done carefully, stirring the solution while pouring the $BaCl_2$ in, a little at a time. The $BaCl_2$ solution should consist of 150 grams of crystallized $BaCl_2$ in about 200 c.c. of distilled water. A dense white precipitate forms on pouring the barium chloride solution into the sodium borotungstate, and this precipitate should be stirred for some minutes so as to thoroughly mix the two liquids. After a few minutes hot water should be added and the precipitate stirred up thoroughly. In a short time the supernatant liquid can be siphoned off from the precipitate. This washing process should be repeated some 10 or 15 times. The white precipitate is next transferred to a large evaporating dish, and about 300 c.c. of dilute HCl added (1 HCl to 10 H_2O); the mixture of precipitate and solution is evaporated to dryness on a water bath, about 40 c.c. of strong HCl being added towards the end.

The dried mass is then treated with about 300 c.c. of hot distilled water, the former being thoroughly broken up into fine powder with a glass rod flattened at one end.

The green sediment of tungstic hydrate is filtered off and washed, the washings being added to the solution of barium borotungstate. The liquid is evaporated down and allowed to stand. Yellow crystals are formed, and with a little care these can and should be obtained as single large crystals. The latter crystallize in two forms, one as modified tetragonal prisms with well-developed basal planes, and the other as flattened forms much resembling hexagonal forms in shape.

Nearly the whole of the barium borotungstate can be obtained, the mother-liquid being evaporated down a little more after each crop of crystals has been obtained. Towards the end of the process transparent colourless platey crystals of barium borate may separate out as well. The barium borotungstate crystals should be dissolved up in water and recrystallized once again. They should then be dissolved up in about 200 c.c. of distilled water and a solution of $ClSo_4$ added from a burette or a pipette, care being taken to add it very slowly, drop by drop as long as a precipitate falls, and the precipitate of $BaSo_4$ is then filtered off and the filtrate is evaporated down in a porcelain dish on a water bath till a piece of olivine floats on the surface. This liquid will be found to have a specific gravity of 3·46 at 60° F., and it takes some hours before some of the salt crystallizes out and the specific gravity falls to 3·28. It might thus perhaps be used for the separation of some minerals of specific gravity greater than 3·46, though care would have to be taken not to allow crystals to form on the lighter minerals and thus sink them.

It will be found that the cost of the chemicals used will come to about three shillings, viz. :—

450 grams	(nearly 1lb.)	sodium tungstate	1*s.*
675 ,,	(nearly 1½lb.)	boric acid	9*d.*
150 ,,	(5¼ ounces)	barium chloride	4½*d.*
25 ,,	(0·87 ounces)	cadmium sulphate ...	6*d.*
Pure hydrochloric acid, filter papers, etc.			4½*d.*

The quantity of cadmium borotungstate obtained is about 160 grams, or 50 c.c. The borotungstate crystals separate out from the solution saturated when hot and are nearly colourless.

The crystals of barium borotungstate obtained earlier in the process cannot be mistaken when once seen. They are light yellow, transparent, and have a splendid lustre. The surface becomes yellow and opaque on washing with water.

The principal difficulty in the manufactnre of this liquid is the care that has to be taken in crystallizing the various salts out from their solutions. There is no reason why any geologist with a little knowledge of chemical manipulation should not make his own heavy liquid, or why the manufacturer should charge such an exorbitant price as at present, as the actual time spent in making it is very small, though spread over several days.

In conclusion, I must express my obligations to Prof. Judd, F.R.S., who has afforded me great facilities in carrying out these operations.

REVIEWS.

I.—An Introduction to the Study of Petrology: the Igneous Rocks. By Frederick H. Hatch, Ph.D., F.G.S. pp. 128. (London, Swan Sonnenschein & Co. 1891.)

THE object of this little book (as stated in the preface) is to describe the mineral constituents and structure of the Igneous Rocks, their mode of occurrence and origin; and the author has fulfilled his task in an accurate, clear, and concise manner.

Petrology is rapidly developing a language of its own, and Dr. Hatch, who has already done good service in explaining the meaning of its many terms in his Glossary (appended to Teall's British Petrography), gives also many useful definitions in his present work. It will be of service, therefore, as a text-book for students who are giving especial attention to Igneous rocks, while to geologists in general it will be a handy book of reference on the principal Igneous rocks, and their distribution in the British Islands. These portions of the subject occupy about one-half of the volume, the other half being mainly devoted to the constituent minerals. We may observe, by the way, that a few diagrams showing the mode of occurrence of the rocks would have been useful.

The title of the book is, perhaps, a little misleading (unless the work be intended to form one of a series), for the author has brought us into the presence of Petrology, without giving us any real introduction. The student will find that he cannot make acquaintance with the subject without a good preliminary knowledge of Optics and Crystallography, to say nothing of Chemistry. Dr. Hatch, it is true, states that the scope of his work is too small to admit the treatment of Optical phenomena, and he refers the student to the lately published and excellent "Notes on a New Form of Polarizing Microscope," by Allan B. Dick. Mr. Dick's "beginner" is told how to measure angles of extinction, and how to observe the "dispersion," and the character of the pleochroism of any mineral, but even he must start with some preliminary training, and Mr. Dick recommends Spottiswoode on Polarized Light.

Thus the student who wishes to master the methods of research, and be enabled to undertake investigations on his own account, must seek help elsewhere. He will find much practical information in Rutley's "Rock-Forming Minerals," but that work is not altogether free from technical terms, that may be familiar to the advanced student, but which might discourage the beginner. Prof. Cole's "Aids in Practical Geology" introduce the subject in a far simpler form, and thus provide more easy lessons on Petrology and its methods of research. Dr. Hatch's book contains only the main facts concerning Igneous rocks, and it will not educate the student to identify his specimens.

Although the identification of Igneous rocks is a task that now-a-days requires much special training, Petrologists unfortunately appear to attach but little importance to rock names. They prefer

to treat the rocks as mineral aggregates and to describe their structure and composition. The field-geologist is mainly concerned with their mode of occurrence and origin; and to him rock-names are a necessity. We are glad to find that the needs of the field-geologist are not neglected by Dr. Hatch. Referring to the classification of the rocks, he says "Chemical composition (as far as the percentage of silica is concerned) and mode of origin or occurrence occupy a chief place. Mineralogical composition is, on account of its extreme variability, allowed to play only a subsidary *rôle*." In this difficult task of furnishing a classification of the Igneous rocks, Dr. Hatch has achieved success.

II.—Dr. H. Filhol on the Fossil Mammals of Sansan.

Études sur les Mammifères Fossiles de Sansan. Ann. Sci. Géol. vol. xxi. Art. 1; pp. 320, 46 plates.

THE small village of Sansan, near Auch, in the department of Gers, has long been celebrated for the number of remains of Mammals found in beds belonging to the *Miocène Moyen* of the French geologists, and also for the beautiful state of preservation in which many of these remains occur. The first in the field to undertake the description of these specimens was the late M. Edouard Lartet, but his investigations appear to have been hampered by the lack of sufficient opportunities for illustrating his descriptions with figures. This want was to a certain extent remedied by the late M. Paul Gervais, Dr. Kowalevsky, and others; but only certain species or groups were fully treated, and we have never had any attempt at a monograph of the Sansan Mammals since Lartet's preliminary catalogue.

In the work before us we now have the whole series of these remains not only well described, but fully illustrated by excellent plates; and all who are interested in this branch of fossil zoology owe a debt of gratitude to Dr. H. Filhol, of the Paris Museum, for the execution of this laborious task. It appears that the Doctor has been in the habit of paying periodical visits to the Sansan quarries during the past three years, and has thus succeeded in obtaining a number of specimens which far surpass most of those hitherto described. Many of Lartet's types have also been fully described and figured for the first time.

The total number of species of Mammals which Dr. Filhol recognizes from these deposits is 78; these being arranged under the heads of 42 genera. In this notice we shall only refer to a few of the species which appear to us of especial interest. Before doing so, we venture, however, to call attention to some instances of carelessness on the part of the author which are exceedingly embarrassing to those who, like the present writer, have to record new genera and species. To begin with, Dr. Filhol never states which of the genera and species to which his name is appended are mentioned for the first time. In the absence of any back reference, it would, however, be natural to assume that when we meet with

names like *Talpa primæva* (Filh.), on p. 35, such specific names are new ones. This, indeed, appears to hold good for that particular instance, and also for *Mustela leptorhyncha* on p. 105. When, however, we turn to *Mustela larteti* on p. 107, we find precisely the same condition, although this specific name was applied by the author in the "Bull. Soc. Philom." for 1888. A still worse instance occurs on page 265, where we find the name *Strogulognathus sansaniensis*, apparently as a new genus and species, without the slightest reference to the fact that the specimens so named had been described by the author in 1888 in the serial cited under the name of *Platuprosopos sansaniensis*. This change of the generic name has been rightly made on account of the preoccupation of the one first applied, but this ought to have been fully notified in the text. Moreover, when he was changing the name, the author might have given the correct *Strongylognathus* instead of the incorrect *Strogulognathus*. It may also be mentioned that in 1888 Dr. Filhol described a Mammal from Sansan under the name of *Choilodon elegans*, although no such specific or generic name occurs in the present work. Whether the omission of these names is due to inadvertence, or whether they have been replaced by others, we are quite unable to say.

Then, again, we notice some very embarrassing errors in regard to references, as well as a large number of misprints. Thus, in a footnote on page 133, the present writer is quoted as *loc. cit.* without the slightest previous mention of any work to which the *loc. cit.* could refer. As instances of carelessness in spelling, we may refer to the generic name *Lanthanotherium* given on page 23, but which appears as *Lantanotherium* on page 317; there being here, again, not the slightest reference that this name first appeared under the latter incorrect form (in which it has been quoted in two Manuals) in 1888. Again, on page 73 *et seq.* we are somewhat surprised to find *Pseudælurus* or *Pseudailurus* modified into *Pseudelurus*; but when we see the author's own genus *Proailurus* repeatedly appearing as *Prailurus*, our astonishment at the way words are treated is still greater. In the index the appearance of *Myogale sansaniensis* immediately after *Mygale sansaniensis* suggests an inadvertent repetition of a name, till we turn to the text and find that *Myogale* is a misprint for *Myolagus*.

We have alluded thus at length to these omissions and errors by which the work is disfigured, as they are so embarrassing to those who have to record and quote from it; but it is with pleasure that we turn to notice some of the more important forms described by the author.

Among the Insectivora, the author has found out that the commonly accepted name *Parasorex* is antedated by *Galerix*, which is accordingly adopted.

In the Carnivora, one of the finest specimens described (pls. ii. iii.) is a nearly perfect skull of *Machærodus palmidens*, which is of especial interest as showing the presence of an alisphenoid canal. This canal being totally wanting in all existing *Felidæ*, its presence

in the Sansan *Machærodus* seems to indicate that this genus, although specialized as regards its dentition, is otherwise a generalized type. The other most interesting Carnivore is the one described by Lartet as *Hemicyon*, but referred by Gervais and Gaudry to *Hyænarctus*. The only specimen of this species that has hitherto been figured is part of an upper jaw with the hinder molars; but Dr. Filhol tells us that the species was originally founded upon the evidence of the mandible. An entire palate and mandible are figured in pls. vii.–ix., which sufficiently show that this animal does not belong to *Hyænarctus*, and as it is certainly not referable to *Cephalogale*, and according to Dr. Filhol is different from *Dinocyon*, it appears entitled to rank as a distinct genus. It may be observed that although the premolars agree with those of *Hyænarctus*, and differ from those of the Dogs, in the absence of fore-and-aft cusps, yet that there are four of these teeth, in place of the three of *Hyænarctus*; the whole four in the lower jaw forming a nearly continuous series. A further difference occurs in the narrower and more trenchant form of the hinder half of the lower carnassial tooth; while Dr. Filhol states that the feet of this animal were digitigrade, those of *Amphicyon*, and doubtless *Hyænarctus*, being plantigrade.

Another equally large Carnivore described by Lartet as *Pseudocyon*, but identified by Pomel with *Amphicyon*, appears likewise entitled to represent a distinct genus. This animal is unfortunately known only by the lower jaw, which agrees in general characters with the half-bear-like half-dog-like animals so common in the Miocene and Pliocene. It presents, however, the unique peculiarity that the first lower premolar is implanted by two distinct roots; the position of this tooth being far behind the canine, instead of close to it as in *Amphicyon*.

In the Ungulates we have a good figure of the skull of *Rhinoceros sansaniensis*, which is regarded as a good species; while a beautiful plate (pl. xvi.) of the jaws of *Anchitherium* with the deciduous and permanent teeth cannot fail to attract attention. Equally important is the fine skull of *Listriodon* shown in pl. xviii., which, in spite of its Tapir-like teeth, is clearly seen to be a true Pig. Space does not admit of reference to the numerous Deer-like Ruminants which are so abundant at Sansan; but we wish that Dr. Filhol had had an opportunity of comparing the jaw figured on pl. xxx. as *Strogulognathus* with that of the existing *Hydropotes*.

Passing by the Antelopes and Mastodons, our few remaining observations must refer to the subject which forms the crowning interest of the whole work—the identity of the limbs described as *Macrotherium* with the skull and teeth of *Chalicotherium*. The association of similar limb bones and teeth, not only at Sansan, but likewise at Pikermi and Samos, as well as in the United States, leaves no doubt that they belong to one and the same type of animal, although it may, of course, prove that there is more than a single genus. Dr. Filhol gives us not only figures of the bones of the feet, but also attempts a restoration of the skeleton. In the

hind-foot, in spite of the long Edentate claws, the general structure is decidedly Perissodactyle; although this is much less marked in the carpus. The teeth, as is well known, are practically indistinguishable from those of some of the more generalized Perissodactyles; and, whether it be eventually proved advisable to retain *Chalicotherium* in that group, or to make it the representative of a distinct suborder of Ungulates, we cannot agree with our author in regarding it as in any way indicating an affinity between the Ungulates and Edentates, which, as has been recently pointed out by Dr. Ameghino, probably have a totally different phylogeny.

In congratulating Dr. Filhol on the completion of this valuable work, we cannot avoid expressing the hope that he may be induced to treat the Mammals of other gisements of the typical French Miocene in a similar manner. R. L.

III.—Guide du Géologue dans le Tertiaire Parisien. Par A. Laville. Pp. 24, Plates I.—X. (Paris, 1890.)

THIS *brochure* will prove exceedingly useful to all students of the Paris basin Tertiaries. There is no attempt at description of the beds; it commences with a table giving the subdivisions and groups of the divers formations within the area; followed by lists of the principal fossils found in them; and concludes with a series of ten maps of typical localities.

In the table the Meudon Conglomerate is classified with the Montian, whilst the Pisolitic Limestone is omitted, presumably because the author prefers to include it in the Cretaceous. The *Limnæa strigosa* marls form the superior limit of the Eocene, and the highest bed of the Oligocene is the Beauce limestone. We cannot agree with the author's classification of the Champigny limestone with the whole of the Gypsum beds; and we do not know how the lacustrine limestone of Ducy can consistently be bracketed with the upper, middle, and lower "sables moyens." If it is to be included in the last-mentioned division at all, it must be placed as the equivalent of the Mortefontaine beds. In regard to the fossil lists, which mostly deal with Mollusca, it is evident that the author has paid much more attention to some genera than to others. He is very ambiguous in his nomenclature, leaving it doubtful in the mind of the reader whether he intends the brackets to include genera, or subgenera, or merely discarded names. The maps form the most valuable portion of the work. They are extracted from the Government Surveys on the 80,000 scale, and clearly indicate the position of the chief sections found within the limits of each district defined. The ten plates of fossils illustrate many carefully-selected characteristic forms.

IV.—The Tertiary Insects of North America. By Samuel H. Scudder. Report of the United States Geological Survey of the Territories. F. V. Hayden, U.S. Geologist-in-Charge. Vol. xiii. 1890, 4to. pp. 734, pls. xxviii.

THIS massive volume contains the results of more than twelve years' labour devoted to the study of the fossil Tertiary Insects

of North America, and even now only the lower orders of Insects have been fully treated; the materials collected within the last twenty years proving as abundant as all those hitherto known from the entire European area. In the Introduction the author remarks, "The pages and plates of the present volume bear testimony to the fact that our Tertiary strata have preserved remnants of an ancient host, so varied in structure, so closely also resembling their brethren of to-day, that nearly or quite every prevalent family-group in the entire range of the insect world has already been demonstrated to have then existed. While often fragmentary and crushed, sometimes beyond recognition, a not insignificant number are sufficiently preserved for us to repopulate the past; sometimes, too, they are preserved in such a wonderful manner that in tiny creatures with a spread of wings scarcely more than a couple of millimètres, one may count under the microscope the hairs fringing the wings."

There are several localities which have yielded the insects herein described, but by far the most important is Florissant, in a narrow valley high up in the mountains at the southern extremity of the front Range of Colorado. The insects are here preserved in an old lake basin, probably of Oligocene age, in shaly beds, now laid bare by erosion, which are wholly composed of volcanic sand and ash, and 15 mètres in thickness. These beds yielded a greater number of insects in a single summer than have been obtained at the celebrated Œningen deposit in thirty years, and a very interesting comparison is made of the percentage of representation of the different groups at the two localities. At Florissant the most numerously represented group is the Hymenoptera, which forms 40 per cent. of the total; followed by the Diptera with 30 per cent., the Coleoptera with 13 per cent., the Hemiptera with 11 per cent., and the Neuroptera with 5 per cent., whilst the Lepidoptera, Orthoptera, and Arachnida together only contribute ·54 per cent.

Great numbers of plants are found associated with the insects at Florissant, and both kinds of organisms indicate a climate considerably warmer than that now prevalent in the locality.

Of probably the same age as the Florissant deposit are the insect-bearing beds of the White River in Western Colorado and Eastern Utah, and of two or three localities in Wyoming. From fine clays of probably Miocene age, at and near Quesnel in British Columbia, Dr. G. M. Dawson obtained numerous insects, mostly Hymenoptera and Diptera; which Dr. Scudder has also described.

Of a more recent age are a considerable number of elytra and other remains of beetles, obtained by Dr. G. J. Hinde in clay beds near Toronto, Canada. Though only of interglacial age, the twenty-nine species determined by Dr. Scudder are all extinct; some of the forms are nearly allied to insects now inhabiting the same district in Canada and the northern United States, whilst the relatives of others now exist in the Lake Superior and Hudson Bay Region.

The author notices some peculiar general features relating to the occurrence of the fossil insects in North America; one, that in

hardly a single instance has the same species been found in two distinct localities, a fact which may perhaps be accounted for by the beds not being exactly synchronous, and the author thinks that the insect remains will prove of more value in the marking of distinct horizons than the plants with which they are usually associated. Another feature is the number and extraordinary proportion of species each so far represented by a single specimen, and, again, that no inconsiderable proportion of the species must be referred to genera no longer existing.

The excellence of Dr. Scudder's work is too well known to require comment, and this present volume is an additional proof of the immense labour and zeal which he brings to his herculean task. Its importance will be fully recognized by all palæontologists on this side of the Atlantic, and its promised further continuance will be gladly welcomed.

REPORTS AND PROCEEDINGS.

Geological Society of London.

I.—April 8, 1891.—Dr. W. T. Blanford, F.R.S., Vice-President, in the Chair.—The following communications were read:—

1. "The Cross Fell Inlier." By Prof. H. A. Nicholson, M.D., D.Sc., F.G.S., and J. E. Marr, Esq., M.A., Sec.G.S.

The tract of lower-Palæozoic rocks lying between the Carboniferous rocks of the Cross-Fell range and the New Red Sandstone of the Eden Valley is about sixteen miles in length, and little more than a mile in average breadth; the Inlier extends in a general N.N.W. and S.S.E. direction, and the normal strike of the rocks is about N.W. and S.E. The tract is divided along its entire length by a fault, which separates the Skiddaw Slates (with the Ellergill Beds of one of the authors and the Milburn Series of Mr. Goodchild) from higher beds on the west. A detailed classification of the Skiddaw Slates is not attempted, but the authors describe the succession of the rocks in the faulted blocks of the western portion. Their classification is as follows:—

Coniston Grits = Ludlow.
Coniston Flags (lower portion) = Wenlock.
Stockdale Shales = Llandovery-Tarannon.
Ashgill Shales.
Staurocephalus Limestone.
Dufton Shales and Keisley Limestone. } = Bala.
Corona Beds.
Rhyolitic Group.

A brief comparison of these rocks with those of other regions is made by the authors.

Two Appendices are added. One by Mr. Alfred Harker, M.A., F.G.S., contains petrographical notices of certain sedimentary and volcanic rocks in the Skiddaw Slates, of the volcanic rocks of the Eycott and Rhyolitic groups, and of the principal varieties of intrusive rocks. The second, by Mr. A. H. Foord, F.G.S., contains a description of some Cephalopods from the rocks of the Inlier.

2. "On the Igneous Rocks of the South of the Isle of Man." By Bernard Hobson, Esq., M.Sc., F.G.S.

Omitting the Foxdale Granite, the oldest igneous rocks of the island appear to be the diabase dykes of Langness, etc., intrusive in Lower-Silurian slates. The Crosby microgranite dyke is also intrusive in these beds, and though its age is difficult to fix, it is probably newer than the Foxdale Granite, which appears to be of post-Lower Silurian and pre-Carboniferous age.

Next come the volcanic rocks of lower-Carboniferous age—an augite-porphyrite series consisting of tuff, breccia, agglomerate, bedded lava, and intrusive masses exposed in a narrow strip extending from Poolvash to Scarlet Point. A vent seems to have been opened during or after the deposition of the Poolvash limestone, from which fine volcanic ashes were ejected to form marine tuff. At intervals between the eruptions the Poolvash marble was deposited, and became interstratified with the tuff. The vent then probably became plugged up, and a violent explosion following supplied material for the agglomerate overlying the tuff. Lava then welled forth, and finally the volcano became extinct, and the intrusive mass of the Stack, regarded by the author as a volcanic neck, was exposed by denudation. It was probably at the close of volcanic activity that a melaphyre dyke was formed resembling the porphyritic olivine-basalt of the Lion's Haunch, Edinburgh.

At Poortown an intrusive mass occurs, provisionally termed augite-picrite-porphyrite, and considered by Mr. J. G. Cumming to be of post-Carboniferous age.

Numerous dykes of ophitic olivine-dolerite occur between Bay-ny-Carrickey and Castletown Bay, at Langness, etc. They are post-Lower Carboniferous, and possibly of early Tertiary age.

Full details with regard to the development and the macroscopic and microscopic characters of the various igneous rocks are supplied by the author, who acknowledges his indebtedness to Prof. Boyd Dawkins for the use of his geological map and notes.

II.—April 22, 1891.—Dr. A. Geikie, F.R.S., President, in the Chair.—The following communications were read:—

1. "Results of an Examination of the Crystalline Rocks of the Lizard District." By Professor T. G. Bonney, D.Sc., LL.D., F.R.S., V.P.G.S., and Major-General C. A. McMahon, F.G.S.

The authors, in company with the Rev. E. Hill, spent a considerable part of last August in examining anew those sections in the Lizard district which had any bearing upon the questions raised since the publication of Professor Bonney's second paper in 1883. They had also the advantage of occasional conference with Mr. Teall and Mr. Fox, whose valuable contributions to the knowledge of the crystalline rocks of the district are well known.

That the Lizard serpentines are altered peridotites may be regarded as settled, but doubts have been expressed as to their relation to other associated rocks, and as to the meaning of a streaky or banded structure exhibited by certain varieties.

The authors, after re-examination of a large number of sections, feel no doubt of the accuracy of their original view that the peridotite was intruded into the hornblende schists and banded "granulitic" rocks, after these had assumed their present condition. In it they find no signs of any marked pressure-metamorphism, either prior or posterior to serpentinization. They have failed to connect the streaky or banded structure with any foliation or possible pressure-structure in the schists, and they can only explain it as a kind of fluxion-structure, viz. as due to an imperfect blending of two magmas of slightly different chemical composition, anterior to the crystallization of the mass.

The Porthalla sections have been examined with especial care, not only because the serpentine is nowhere so conspicuously banded, but also because its intrusive character has been denied, both it and the hornblende schists being ascribed to the alteration of a series of sedimentary rocks of suitable composition. For this view the authors have failed to discover any evidence, and consider it contrary to stratigraphical and petrographical facts.

In regard to the genesis of the crystalline schists, which for purposes of reference were divided by Prof. Bonney into a "granulitic," a "hornblendic," and a "micaceous" group, the authors show that in parts of the first the more acid rock breaks through the more basic, as if intrusive, in others they appear to be perfectly interstratified, the one passing backwards and forwards, though rapidly, into the other. But between these extremes, intervals can be found where the two rocks seem as if partially drawn out together. The authors are agreed that certainly one, probably both, of these rocks are igneous, that when the basic rock was solid enough to be ruptured, the acid magma broke into it, and sometimes softened it sufficiently to allow of the two flowing for some little distance together, after which crystallization took place. In regard to the hornblende schists, the authors are not yet satisfied that either fluxion or mechanical crushing will account for every structure which they have examined, and prefer to leave the question, in certain cases, an open one. The most distinctive features of the micaceous group appear due to subsequent earth-movements, so that, though it exhibits some special characteristics, the authors are doubtful whether it is any longer worth while separating it from the hornblende schists.

Of the igneous rocks newer than the serpentine, the gabbro has received the closest attention. It exhibits in places (especially in the great dyke-like mass as Carrick Luz) a very remarkable foliation or even mineral banding, which has been claimed as a result of dynamo-metamorphism. The authors bring forward a number of instances to establish the following conclusions:—(*a*) That this foliation occurs most markedly where the adjacent serpentine does not show the slightest sign of mechanical disturbance; (*b*) that it must be a structure anterior to the consolidation of the rock; (*c*) that it sets in and out in a very irregular manner; (*d*) that when it was produced the rock was probably not a perfect fluid. Hence they explain it also as a kind of fluxion structure, produced by differential

movements in a mass which consisted of crystals of felspar and pyroxene, floating thickly in a more or less viscous magma.

The authors' investigations tend to prove that (*a*) structures curiously simulative of stratification may be produced in fairly coarsely crystalline rocks by fluxional movements anterior to crystallization; and that (*b*) structures which of late years have been claimed as the result of dynamo-metamorphism subsequent to consolidation must have, in many cases, a like explanation. This is probably the true explanation of a large number of banded gneisses which show no signs of crushing and holocrystalline, but in their more minute structures differ from normal igneous rocks.

The authors have seen nothing which has been favourable to the idea that pressure has raised the temperature of solid rocks sufficiently to soften them.

2. "On a Spherulitic and Perlitic Obsidian from Pilas, Jalisco, Mexico." By Frank Rutley, Esq., F.G.S.

The specimen described is a leek-green rock with waxy lustre. The sequence of the structures developed in it is made out to be as follows:—First, the development of fluxion-banding; next, the formation of spherulites; and then the setting up of a perlitic structure, the fissures of which were finally sealed by the introduction of chalcedonic matter.

A wavy transverse banding in the spherulites is apparently due to a temporary check which the fluxion-bands have exerted on the development of the crystalline bundles of the spherulites. In one case a spherulite has been developed prior to the formation of a similar but larger one which encloses it. Some of the spherulites envelope small crystals of triclinic felspar.

The author considers it very probable that the obsidian has been subjected to hydrothermal agency since its solidification, and subsequent to the development of its perlitic structure, and gives reasons for this view.

III.—May 6, 1891.—Dr. A. Geikie, F.R.S., President, in the Chair.—The following communications were read:—

1. "On a Rhætic Section, at Pylle Hill or Totter Down, Bristol." By E. Wilson, Esq., F.G.S.

In a deep railway-cutting at Pylle Hill, the Rhætic beds, having a thickness of not more than seventeen feet, are exposed between the Tea-Green Marls and the Lower Lias. There is no doubt as to the division between the Rhætic and Keuper beds in this section, but the line of demarcation between the Rhætic and the Lias has always been a matter of uncertainty in the West of England. In connection with this subject the term "White Lias," as applied to beds some of which are Rhætic and others Liassic, is held to be unsatisfactory. The author takes a limestone which is the equivalent of the Cotham Marble as the highest Rhætic bed in the section described. He divides the Rhætic beds of the cutting into an Upper-Rhætic Series and *Avicula-contorta* Shales. The intimate connexion betwixt the Tea-Green Marls and the Red Marls of the

Upper Keuper is well displayed, whilst there is a sharp line of demarcation between the former and the *Avicula-contorta* Shales. Most of the characteristic fossils of the British Rhætic are met with at Pylle Hill, together with a few forms which are new to England, and some of these possibly new to science.

A detailed section of the subdivisions of the Rhætic and adjacent beds, and a list of Rhætic fossils found in the section, are given by the author.

2. "A Microscopic Study of the Inferior Oolite of the Cotteswold Hills, including the Residues insoluble in Hydrochloric Acid." By Edward Wethered, Esq., F.G.S., F.C.S., F.R.M.S.

The author gives the following main divisions of the Inferior Oolite of the Cotteswold Hills in descending order:

Ragstones.
Upper Freestones.
Oolitic Marl.
Lower Freestones.
Pea Grit.
Transition beds resting on Upper Lias.

The strata are described, and the results of microscopic examination of the different beds given. These latter confirm the author's views as to the important part which *Girvanellæ* have taken in the formation of oolitic granules; whilst an examination of the borings referred to by Prof. Judd in the discussion of Mr. Strahan's paper "On a Phosphatic Chalk" convinces the author that these have no connexion with the genus *Girvanella*.

In the second part of the paper the insoluble residues left after treating the various deposits with acid are considered. They contain chiefly detrital quartz, felspars, zircons, tourmaline, chips of garnet, and occasionally rutile. In the argillaceous beds silicate of alumina was found to occur plentifully. The detrital material is considered to be due to denudation of crystalline felspathic rocks, and not of stratified ones. This view seems to be supported by the quantity of felspar and its good state of preservation.

The paper concludes with a consideration of the quantity of residue and the size of the quartz-grains in the different deposits, which are summarized in the following table:—

	Percentage of Residue.	Size of quartz grains, in millim.
Ragstones	2·8	·17
Upper Freestones.....	1·1	·12
Oolitic Marl	3·2	·09
Lower Freestones.....	1·8	·13
Pea-Grit Series	5·0	·14
Transition Beds	38·3	·13

This shows a great falling off in the percentage of residue above the Transition Beds. That of the Freestones is remarkably low, and it would appear that these rocks were formed under conditions which allowed of very little sediment being deposited.

ERRATUM.—In the May Number, p. 240, last line but one of first paragraph, *for* "Metamorphic" *read* "Metatropic."

CORRESPONDENCE.

ELEVATION OF AMERICA IN THE TERTIARY PERIODS.

SIR,—I notice in recent numbers of the GEOLOGICAL MAGAZINE that Mr. Upham has been discussing his views on the elevation of the Gulf of Mexico, etc. It seems a pity that gentlemen, who desire to launch such startling hypotheses, should not devote more time to settling the facts upon which these hypotheses are based, before promulgating their new views. As the statements made by Mr. Upham may by many be taken as properly verified, and more confusion be thereby occasioned, permit me to call attention to a few facts which have been verified.

1. The late Dr. Maack when on the isthmus of Darien did not collect any Pleistocene fossils from the summit of the Atrato divide 763 feet above the sea. 2. The Pleistocene fossils collected by Dr. Maack were from an elevation of only 150 feet on the Panama side, ten miles from Panama city. The fossils above this height collected by Dr. Maack are Eocene or Miocene exclusively, and related to the Miocene fauna of Santo Domingo, as indeed was pointed out by Gabb nearly twenty years ago (Proc. Am. Phil. Soc. vol. xii. p. 572). 3. The summit or dividing ridge is not fossiliferous, and is probably not later than the Mesozoic epoch.

I may add, from information to be shortly published, that the supposed great elevation of Florida at any time since the later Eocene is as improbable as any hypothesis which could well be conceived. The conclusions which the facts necessitate in the case of Florida may be briefly outlined as follows:—During the later Eocene, west central Florida was an island, like one of the Bahamas at present, composed exclusively of organic marine sediments which in the Vicksburg epoch attained an unbroken thickness of more than 1000 feet. The whole submarine plateau above which the present Florida rises may turn out to be of this age and constitution. This island had a land-shell fauna derived from the south. The strait between the island and the main coast north of it was more than fifty miles wide at the narrowest point, and was only closed at the beginning of the Pliocene. There have been gentle changes of level since the Eocene, but nothing violent, and the vertical range has been small. The Eocene and the old Miocene faunas were of a subtropical character like the Antillean fauna at present. A change took place in Mid-Miocene by which a cool, temperate, or colder water fauna invaded the Floridian region from the north, and about 200 feet of strata (Chesapeake Group) were deposited; equivalent to the well-known Miocene beds of Virginia and Maryland. With the elevation which connected the Floridian islands with the continent a warmer era was again inaugurated in the sea, and an invasion of Pliocene Vertebrates began, on the Peninsula of Florida.

There were unquestionably great changes of level on the continent, increasing as one goes northward, both in Miocene and Pleistocene times. In the Antilles it has been proved that great changes have taken place. But the Floridian region, for some unknown reason, escaped, and Yucatan, probably, also.

I have been making a special study of Floridian Geology for some years, and hope to publish a considerable amount of new information on that subject during the coming summer.

SMITHSONIAN INSTITUTION, U.S. NATIONAL MUSEUM,
WASHINGTON, *April* 15, 1891. WM. H. DALL.

THE GEOLOGY OF THE SALT RANGE OF THE PANJAB.

SIR,—In the latest number (part i. vol. xxiv.) of the Records of the Geological Survey of India there is an interesting paper by Mr. C. S. Middlemiss on the Geology of the Salt Range of the Panjab. Admirable sections are given illustrating two points until recently in dispute, the positions of the Conularia Bed and of the Obolus Shales; and a very bold beginning is made of a fresh discussion, regarding the age and mode of origin of the Salt Marl and its minerals, advocating peculiar eruptive conditions connected with a primitive and hitherto undisturbed subterranean magma. Until Mr. Middlemiss developes his position, it would be premature to comment thereon; I will only ask leave to correct two personal errors in the paper. On p. 25 a quotation is made from my paper on the geology of the Panjab, published in the Provincial Gazetteer, whereby I am made to appear as executing an erroneous reversal of opinion upon a disputed unconformity in the Salt Range. Mr. Middlemiss must have overlooked the note at the beginning of the section on the Salt Range, stating that "this sketch is by Mr. Wynne." I did not alter a word of it. So the passage in question is a repetition by Mr. Wynne of a view against which I had remonstrated in vain. The other point is on p. 20, where I am represented as "not entirely agreeing" with the erroneous view of the Conularia horizon. It refers to a short paper in which I had endeavoured to soften a somewhat acrimonious dispute by an impartial summary of the evidence; but there can be no doubt as to which side my own opinion leaned. I even suggested the conclusion which Mr. Middlemiss now presents as established: regarding the "pebbles" with Conularia I asked—"Is it not more plausible to suppose that they were washed into the gravel bed from some contemporaneous (Palæozoic) pool deposit close by?" (Records, vol. xix. p. 133).

CLIFTON, 29*th April*, 1891. H. B. MEDLICOTT.

OBITUARY.

WE regret to record the death of Professor Joseph Leidy, the distinguished American physiologist and palæontologist. The deceased, who was in his sixty-eighth year, was Professor of Anatomy in the University of Pennsylvania, and of Natural History in Swarthmore College. He was also President of the Academy of Natural Sciences of Philadelphia, Director of the Department of Biology in the University, and a Foreign Member of the Geological Society of London. His more important contributions to scientific literature were, "The Extinct Mammalian Fauna of Dakota and Nebraska," and "Freshwater Rhizopods of North America." He also wrote an elementary treatise on human anatomy.—*Standard*, Friday, 1st May, 1891.